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ORIGINAL PAPERS

A PRELIMINARY PETROGRAPHIC STUDY OF PORTLAND CEMENT[1]

BY JOSEPH L. GILLSON[2] AND ELMER C. WARREN[3]

ABSTRACT

A microscopic study was made of the clinker of five commercial brands of cement. Three crystalline compounds make up over 95 % of these clinkers. The optical properties of two of these were determined; one, the principal constituent, is uniaxial and negative and has indices of 1.726 and 1.730. The other is biaxial and positive and has indices of 1.718, 1.720 and 1.733. This compound was found in both the clinker and the set concrete, proving that it is an inert substance without hydraulic properties. The optical properties of these compounds are not the same as those of any of the members of the CaO-Al_2O_3-SiO_2 system determined by Rankin and Wright.

Several petrographic studies of Portland cement have been made by Colony,[4] by Rankin and Wright,[5] by Rankin,[6] and by Bates and Klein.[7] Colony worked with thin sections of Portland cement, while

[1] Received June 22, 1926.

[2] Assistant Professor of Mineralogy, Mass. Institute of Technology.

[3] Assistant, Dept of Physics, Mass. Institute of Technology.

[4] R. J. Colony, "Petrographic Study of Portland Cement," *School of Mines Quart.*, Vol. XXXVI, Nov., 1914.

[5] G. A. Rankin and F. E. Wright, "The Ternary System CaO-Al_2O_3-SiO_2," *Amer. Jour. Sci.*, 39 [4], 74–75 (1915).

[6] G. A. Rankin, "Portland Cement," *Jour. Frank. Inst.*, June, 1916, pp. 747–84.

[7] P. H. Bates and A. A. Klein, "Properties of the Calcium Silicates and Calcium Aluminates Occurring in Normal Portland Cement," U. S. Bur. Stand., *Tech. Paper*, No. 78, p. 28, 1917.

the other investigators worked with synthetic, pure compounds of calcium, aluminum, and silica. They determined the possible combinations of these elements under laboratory conditions and then suggested what the probable mineral constituents of Portland cement are. Naturally, the question suggests itself: are the actual constituents of Portland cement clinker identical in their properties with the synthetic materials which have been formed under laboratory conditions?

In order to answer this problem, the authors made a petrographic study of five[1] common brands of Portland cement. It was found that the ground clinker as sold in retail stores, is too fine to be readily studied by optical methods. Accordingly, samples of the unground clinker in the form in which it comes from the kiln were obtained from the manufacturers. This clinker was then ground only to 140-mesh, a screen which yields about the optimum particle size for working with grains mounted in index of refraction liquids under the petrographic microscope. Although the great majority of the crystals in the clinker are very small, the larger ones are preserved by this degree of grinding, and on them the interference figures so necessary to the optical determination of the crystals can be obtained.

Minerals in Clinker

Three minerals make over 95% of the mineral composition of each of the five clinkers. Although at least two other crystalline constituents occur in subordinate quantities, they can have little or no effect on the properties of the cement. They were not determined optically.

Of the three major constituents, two greatly predominate and large enough crystals of them occur to permit optical investigation. The third substance is present as a very finely divided brownish powder, which forms a coating on the grains of the other constituents.

The optical properties of the three major constituents are as follows:

1. Uniaxial, optically negative, with indices of refraction of 1.726 and 1.730. The mineral is very abundant and occurs in colorless crystals.
2. Biaxial, optically positive, optic angle about 20°, with $\nu > \rho$ extreme, and indices of refraction of 1.718, 1.720, and 1.733. It is less abundant than No. 1, and occurs as clusters of small, spherical grains having a brownish color and which are held in a matrix of the third constituent.
3. The brown powder which coats grains of the other constituents, particularly the second, has an index of refraction greater than 1.86, and resembles iron oxide. It may represent the mineral containing the iron known to be in Portland cement. The brown color of the powder seems to be a superficial stain, for in some cases clear crystals can be seen beneath the coating. The grains are always too minute to permit optical study.

[1] Atlas, Lehigh, Edison, and two brands of Iron Clad.

By comparing these properties of the actual constituents of Portland cement with the properties of the artificial materials, it is clear that the commercial cement consists of minerals whose properties are not identical with those of the synthetic compounds. The following data are from Rankin and Wright.[1] They are the optical properties of the several compounds of calcium, aluminum, and silica that these men were able to make in the laboratory.

Composition		γ·2CaO·SiO$_2$	β·2CaO·SiO$_2$	α·2CaO·SiO$_2$	β·$\frac{3}{2}$CaO·SiO$_2$	3CaO·SiO$_2$	3CaO·Al$_2$O$_3$
Crystal system		Monoclinic(?)	Orthorhombic or monoclinic	Monoclinic or triclinic		Monoclinic(?)	Isometric
Crystal habit		Prismatic	Irregular grains—prisms	Irregular grains	Equant grains	Equant grains	Equant grains
Cleavage		001 100	Poor			p(111)	p(110)
Elongation		r α					
Optical orientation		$b=\beta$ $c:\gamma=3°$(?)		$c:a=18°$		$c=\gamma$	
Index of refraction	α	1.642	1.717	1.715			
"	β	1.645		1.720			
"	γ	1.654	1.735	1.737	1.715	1.715	1.710
Character		−	+	+	+	−	
Optic angle		$2E=52°$	Large	Large	Uniaxial or small angle	Uniaxial or small angle	

The only resemblance between the commercial product and the synthetic minerals lies in the similarity between β2CaO.SiO$_2$ and the biaxial positive constituent found in the commercial cement. However, the optic angles of the two minerals are not the same, indicating that there is some difference between them. The most abundant constituent of the commercial cement does not have properties closely similar to any of the synthetic minerals, the index of refraction being higher than that of 3CaO.SiO$_2$.

The two major crystals differ in specific gravity, and an attempt was made to utilize this fact in the preparation of fractions for analysis in the hope that the chemical composition of each would be determined. A complete and clean separation of each mineral could not be realized, due to the intimate intergrowth of the several constituents, but two fractions were obtained, one with about 60% of No. 1 and 35% of No. 2, and another with about 75% of No. 2, and 15% of No. 1.

[1] G. A. Rankin and F. E. Wright, *op. cit.*, p. 3.

These two fractions were chemically analyzed by L. F. Hamilton of the chemistry department of the Massachusetts Institute of Technology. The analyses of the two fractions were so similar that no satisfactory conclusions of the compositions of the two major constituents could be drawn. In fact, the similar analyses suggest that the two major constituents of Portland cement are calcium aluminum silicates. However, the impure nature of the analyzed fractions permits little faith to be placed in the analyses.

Set Cement

It was not within the scope of this investigation to study the set cement, but a number of specimens were examined. The microscope shows crystals in the neat cement which differ from those in the dry clinker, but the brown clusters of spherical crystals of the biaxial positive mineral are found in the set cement as well as in the dry clinker. Evidently this constituent is inert and is unaffected by water, a fact further substantiated by X-ray examination.

The X-ray study of the clinker and of the neat cement was done by Hull's method, which consists in powdering an amount of the substance under investigation and then placing some of this powder in a beam of monochromatic X-radiation. The powdered crystals will diffract the beam according to Bragg's law. The results show that the same diffraction lines are produced by both dry clinker and neat cement. This indicates one of two things. Either no new crystals are formed on hydration, or one or more constituents are present in both clinker and set cement. No extensive study was made by this method, but since new crystals are known to form, the presence of the same diffraction lines in the spectra given by the clinker and the neat cement proves that there is at least one common constituent.

This article is a preliminary report, and it is planned to continue the study of cement by the petrographic microscope with the hope of proving just what these constituents are, and of finding out what are the new crystals that do form during setting.

The authors take this opportunity to express their thanks to C. L. Norton for arranging the financing of this investigation through the Division of Industrial Coöperation and Research of the Massachusetts Institute of Technology, and to J. T. Norton for his aid and interest in the X-ray analysis of the clinker and neat cement.

Massachusetts Institute of Technology
Cambridge, Mass.

THE THEORY OF PICKLING OF SHEET IRON AND STEEL FOR ENAMELING PURPOSES[1]

By Homer F. Staley[2]

ABSTRACT

The fundamental principal of efficient pickling is that efficient pickling does not depend on the solution of a large amount of metal but on the solution of a very thin layer of metal directly beneath the scale, rapidly and with copious evolution of hydrogen. The activity of an acid solution depends on the amount of acid present, the fraction of the acid that is ionized, and on the speed with which the ions move. Since the electrical conductivity of an acid solution is a measure of both the hydrogen-ion concentration and the speed at which the ions move, the electrical conductivities of a series of acid solutions indicate the relative activities of the various solutions. The most effective concentrations of acid lie between 15 and 20%. Heating acid solutions reduces their viscosity and renders the particles more mobile, thus increasing the activity of the solutions. Sulphuric acid is cheaper in first coat than hydrochloric acid, but the latter acts more rapidly and the pickling is completed with less solution of iron. Additions of small amounts of common salt (sodium chloride) have a marked effect on increasing the rate of pickling of sulphuric acid baths. This is due to the formation of a corresponding amount of hydrochloric acid. The chief action of addition agents is to reduce the amount of acid vapor in the fumes from pickling vats and thus permit the use of highly efficient concentrations of acid (between 15 and 20%). Hydrogen absorbed by metals during pickling may be largely removed by immersing the metal in boiling hot water for a few minutes.

Introduction

In enameling technology "pickling" consists of treating the metal to be enameled with acids. The object of pickling is to remove any oxide and slag scale adhering to the surface of the metal.

Mechanism of Pickling

Contrary to earlier theories, recent investigations have shown that the actual solution of oxide of iron in the pickling operation is almost negligible and that the principal action is the attack of the acid on the underlying metal. The acids penetrate the coating of scale and attack the metal beneath. The metal is eaten away with evolution of large amounts of hydrogen and the scale is loosened from the surface of the metal. The iron goes into solution as ferrous sulphate or ferrous chloride, as the case may be. Some of the hydrogen formed is absorbed by the metal while the remainder passes up through the solution and into the air together with the steam and any other gases. The scale which is but slightly, if at all, attacked, falls to the bottom of the bath.

The fundamental principal of efficient pickling is that efficient pickling does not depend on the solution of a large amount of metal

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Enamel Division) Received June 22, 1926.

[2] Manager, Ceramic Dept., Metal and Thermit Corp., New York City.

but on the solution of a very thin layer of metal directly beneath the scale, rapidly and with copious evolution of hydrogen.

Factors that effect the efficiency of the pickling operation are:

1. Concentration of acid
2. Temperature
3. Kind of acid
4. Salts formed in the bath
5. Salts added to the bath
6. Addition agents
7. Use of electric current

Effect of Concentration of Acid

Numerous investigators have studied the effect of variation of concentration of acid in the pickling bath on the rate of pickling. Data and curves showing this effect have recently been published by J. T. Robson.[1] It has been found that whatever acid or mixture of acids is used, the effect is always the same. With very dilute acid solutions the time of pickling is long. As the concentration of acid increases the time of pickling rapidly decreases and reaches a minimum at between 15 and 20% actual acid. As the concentration increases beyond that point, pickling gradually slows up, and when very high acid concentrations are reached, pickling becomes very slow or stops entirely.

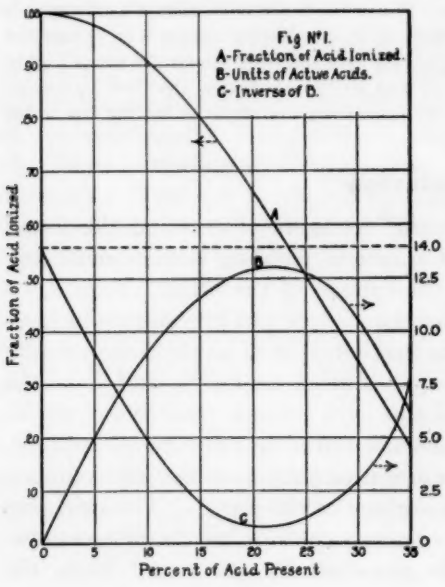

FIG. 1.

The explanation of this seemingly curious variation in time required for pickling with variation in concentration lies in the fact that when acids are present in solution, only a certain percentage of the acid is active. This part is said to be ionized, because the acid molecules are split up into hydrogen ions and non-metallic radical ions. These hydrogen ions are the part of the acids that give them their characteristic properties and are the part that really do the pickling. Another factor is the speed with which the ions move. Therefore, the activity of an acid solution depends on the amount of acid present, the fraction of the acid that is ionized; in other words, on the hydrogen-ion concentration, and on the speed with which the ions move.

[1] *The Enamelist*, July, 1925, pp. 15–19; Oct., 1925, pp. 14–17; Nov., 1925, pp. 5–8.

Effect of Concentration on Hydrogen-Ion Concentration

It has been found that the fraction of acid that is ionized or active is very high in dilute acid solutions and that this fraction decreases at an ever increasing rate as the concentration of acid in solution increases. A typical example is given in Fig. 1, curve *A*. The units of active acid shown in curve *B* are found, of course, by multiplying the percentage of acid present by the fraction that is ionized; in other words, curve *B* shows the hydrogen-ion concentration. Since the time of pickling is the inverse of the hydrogen-ion concentration, in order to get a direct comparison between time of pickling as actually determined and hydrogen-ion concentration, we reverse curve *B*. This gives us curve *C*. From a study of curve *C* we expect the time of pickling to be at a minimum with concentrations of acid between 18 and 25%.

Effect of Concentration on Speed of Ions

The speed at which the ions move gradually decreases as the concentration increases. This effect is particularly noticeable in concentrated solutions of sulphuric acid due to the high viscosity of such solutions. Consequently the rate of pickling at atmospheric temperatures with concentrated solutions of sulphuric acid is less than proportional to the hydrogen-ion concentration.

Significance of Electrical Conductivity of Acid Solutions

Since the electrical conductivity of an acid solution is a measure of both the hydrogen-ion concentration and the speed at which the ions move, the electrical conductivities of a series of acid solutions indicate the relative activities of the various solutions. For the two acids commonly used in pickling, these are as follows, at atmospheric temperatures:

	Conductivity						
Per cent acid	5	10	15	20	25	30	35
H_2SO_4	0.34	0.63	0.74	0.70	0.60	0.49	0.39
HCl	0.37	0.66	0.76	0.77	0.72	0.66	0.59

Since the time required for pickling varies inversely as the activity of the acid solution, by reversing these curves we get curves giving the relative times required for pickling with the various acid solutions, other conditions being kept constant. These reversed curves are shown in Fig. 2 and are found to be remarkably similar to those of Dr. Robson. It is to be noted that the effect of introducing speed of ions as a factor is to throw the minimum slightly toward lower concentrations than when hydrogen-ion concentration alone is plotted so that in this case it falls between 15 and 20% actual acid.

Effect of Temperature

Increase of temperature drives back the ionization of acid solutions slightly and thus reduces the hydrogen-ion concentration somewhat.

On the other hand, it reduces the viscosity of the solutions and thus increases the speed of movement of the ions. This effect is the more pronounced and therefore in general pickling proceeds more rapidly with heated solutions. Since the effect is mainly produced by a reduction of viscosity, it follows that heating is not important with hydrochloric acid solutions, since these are already quite fluid, but is quite necessary with sulphuric acid solutions, particularly those of fairly high concentration since these are quite viscous, and without the application of heat the movement of the ions is so retarded that the action of the acid is quite sluggish.

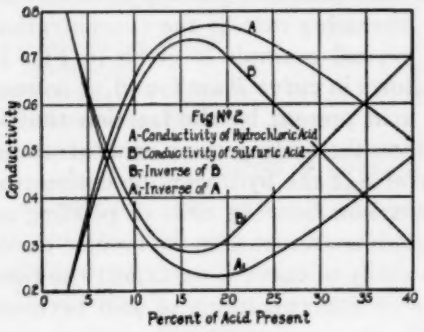

FIG. 2.

Effect of Kind of Acid

Sulphuric Acid Sulphuric acid is most commonly used due to its cheapness. The concentration employed varies from 3 to 20% actual acid. The usual operating temperatures of the bath range from 140 to 175°F (60 to 80°C). The rate of pickling with sulphuric acid is slow and the attack on the metal is pronounced. Therefore, the ware pickled with sulphuric acid is liable to be pitted. Heating of the bath is essential to maintain even a fairly rapid rate of pickling. The acid-bearing fumes rising from the hot bath are very obnoxious to workmen. In fact, it seems that the only advantage in pickling with sulphuric acid lies in the original first cost of the acid.

Hydrochloric Acid Hydrochloric acid is used in concentrations of 3 to 20% actual acid. The usual operating temperatures of the bath are from 75 to 120°F (25 to 50°C). The action of hydrochloric acid is much more rapid than that of sulphuric acid and it does not attack the iron so much or cause as much pitting of the ware. The amount of iron dissolved in the pickling operation is only about half that dissolved in pickling with sulphuric acid. This is an illustration of the principle that efficient pickling does not depend on the solution of a large amount of iron but on the solution of a very thin layer of iron directly beneath the scale, rapidly and with copious evolution of hydrogen. Since the bath is run at lower temperatures without generation of steam, the fumes are not so great in volume or so highly acid as in the case of sulphuric acid baths. The main drawback to the use of hydrochloric acid for pickling lies in its high first

cost compared to the cost of sulphuric acid. Some enamelers claim that chlorides cause pinholes in enamels, but on the other hand, other enamelers claim that sulphates cause blisters in enamels.

Mixed Acids To gain part of the advantages of pickling with hydrochloric acid without incurring the disadvantage of its excessive first cost when used alone, recourse is sometimes had to the use of a mixture of hydrochloric and sulphuric acids. In general, the time required to pickle with mixed acids is intermediate between what would be required using either alone. On the other hand, in the experiments of Dr. Robson,[1] the rate of pickling is more rapid than would be calculated from the relative amounts of the two acids present and the rate at which each of them do pickling when used alone in the same concentration as that of the mixture of acids. In Dr. Robson's example 12% sulphuric acid at 120°F pickles steel in five minutes and 12% hydrochloric acid pickles steel in one minute. By simple calculation of mixtures we would expect a mixture of two parts sulphuric acid and one part hydrochloric acid having a total concentration of 12% acid to do pickling at 120°F in $3\frac{2}{3}$ minutes. Actually it takes only $1\frac{1}{2}$ minutes.

Therefore, there are decided practical advantages in the use of a mixture of acids. Whether this advantage will counterbalance the extra expense of using hydrochloric acid in connection with sulphuric depends upon the relative cost of the two acids at a given time and place.

Mixed acids are used in concentrations of 3 to 20% actual total acid and at temperatures intermediate between those used for sulphuric acid and those used for hydrochloric acid.

Formation of Salts

It is well known that the activity of a pickling bath gradually decreases even though fresh acid is added to it from time to time to bring the acidity back to the original strength. This is due to the fact that the fractional part active of any acid in solution is decreased by the presence in the solution of salts of the acid. In this case it is chiefly salts of iron that cause the retardation of activity, but any other salt of the same acid would have the same effect. Salts of other acids would cause little, if any, retardation.

Attempts are sometimes made to overcome this difficulty when hot acid baths are used by cooling the bath to remove part of the salts by crystallization. Unfortunately, the iron salts of the acids commonly used in pickling are soluble almost to the same degree in cold solutions that they are in hot ones and, therefore, the amount that can be separated out by cooling is comparatively small. It is usual practice

[1] *The Enamelist*, 3, pp. 5–8, November, 1925.

to raise the temperature of the bath as the amount of salts in solution increases in order to get the benefit on activity of heating the acid mentioned above, and finally, to discard it when it is no longer sufficiently active at the highest working temperature.

Addition of Salts

Sodium Chloride Some of the advantages of using a mixture of sulphuric and hydrochloric acids can be gained, at a very slight expense, by the addition of common salt (sodium chloride) to a sulphuric acid bath.

When common salt is added to a sulphuric acid solution it reacts with the sulphuric acid to form hydrochloric acid and sodium sulphate. The result is that we have a bath consisting of a mixture of sulphuric acid and hydrochloric acid but in addition have present a certain amount of sodium sulphate.[1] This sodium sulphate is a slight detriment in that it retards the action of the sulphuric acid to a slight extent, but this is more than counterbalanced by the increased activity of the bath as a whole due to the presence of the hydrochloric acid.

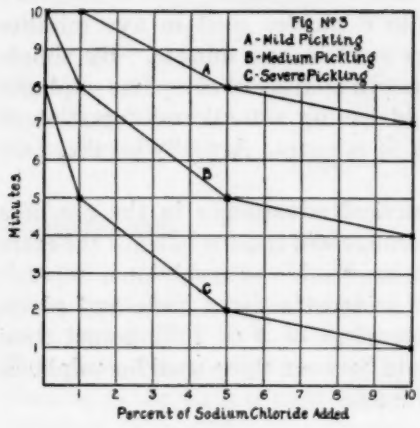

FIG. 3.

In Fig. 3 are shown the results obtained in the laboratory of the writer on adding various amounts of common salt to a sulphuric acid pickling solution. The solutions were all kept at 120°F (50°C). It will be seen that even small additions of salt have a decided effect in accelerating the action of the bath. These tests were made with fresh acid solutions but other tests made by the writer with acids containing large amounts of ferrous sulphate and with larger additions of salt have shown that the beneficial effects of the addition of salt to sulphuric acid pickling baths are quite marked at all stages in the life of the bath.

To the best knowledge of the writer, the use of salt in sulphuric acid pickling baths is not practiced at present in the enameling industry. Since it is such a cheap and handy method of increasing the efficiency of pickling baths it should be worthy of trial on a large scale.

[1] From the standpoint of strict chemical accuracy we know that a small part of the sodium will be there as sodium chloride, but this may be neglected in this discussion.

Niter Cake Niter cake also may be used for pickling. The composition of this material varies widely, but averages about 35% sulphuric acid and 65% sodium sulphate. The acid does the pickling. The sodium sulphate not only does no pickling but when present in such very large amounts, slows down the action of the acid. Its action is exactly similar to that of ferrous sulphate in ordinary sulphuric acid pickling, and is in accord with the rule that the presence of large amounts of a salt of an acid in solutions of that acid render the acid less active.

In order to overcome this retardation in activity, it is necessary to run a niter cake bath of a given acidity at a higher temperature than a straight sulphuric acid bath of the same acidity. It is evident, therefore, that when purchased for pickling, niter cake should be paid for on the basis of its acid content and that the price for unit of acid should be less than that paid for straight sulphuric acid.

It is claimed for niter cake that owing to the fact that its action is less violent than that of straight sulphuric acid there is less pitting of the metal with its use. However, the same reduction in activity of sulphuric acid can be obtained by allowing ferrous sulphate to accumulate in the bath.

Use of Addition Agents

During the past few years the use in pickling baths of small amounts of "addition agents" or "inhibitors" has been advocated. In general, these have been sold as secret proprietary compounds. However, it is known that most of them are colloidal in nature and of organic origin. Materials that have been used for this purpose are molasses, sugars, cornstarch, spent tanning liquor, rye flour, and sulphite liquor.

Some extraordinary claims are made for the proprietary "inhibitors," the chief of these being that in some mysterious way they cause the acid to attack the iron scale and not to attack the iron. It seems inconceivable that the small amounts used could bring about such a radical reversal of the well-known action of the strong mineral acids used for pickling. It is claimed, also, that these inhibitors decrease or eliminate the formation of hydrogen. However, we can definitely say at this time that if no hydrogen is formed there will be practically no pickling. The hydrogen may be absorbed later or used up in a secondary chemical reaction but it must be formed for pickling to take place with any degree of speed.

It should be emphasized that while many of the claims made as to the action of these inhibitors have little basis either in fact or chemical theory, they do perform functions which, under certain conditions, are very desirable.

While many chemical theories have been advanced as to the action of these inhibitors, it is probable that their chief action is not chemical at all but mechanical. While they do not prevent the formation of hydrogen they do prevent it rushing up in jets and carrying with it acid vapors. The inhibitors cause a blanket of foam to form on the surface of the pickling bath and the hydrogen and steam gradually work through this blanket and pass quietly off into the air without carrying with them any acid vapors. Since both hydrogen and water vapor are in themselves odorless, tasteless, and non-irritating to human membranes, if they do not carry acid vapors they can be evolved in large quantities without being injurious or offensive to workmen.

Thus the use of inhibitors makes it possible for men to work in comfort around a pickling bath that is high in acid and which is working rapidly with consequent copious but quiet evolution of hydrogen. As we have seen, the efficiency of pickling baths increases with acid concentration up to about 20% acid. The use of inhibitors renders possible the use of such highly efficient concentrations and thus reduces the time of pickling, the acid consumption, and the amount of metal dissolved.

Another beneficial action of colloidal addition agents is that, due to certain electrical properties of all pickling baths which we need not discuss here, they tend to be deposited most heavily wherever the solution of metal is taking place especially rapidly. Thus they are deposited heavily on clean metal and around little slag spots and less heavily on spots still coated with scale. Since colloidal deposits retard solution, this selective deposition retards solution of metal where it is not needed and permits it to take place more rapidly where it is needed, that is, at spots still coated with scale. In this way excessive solution of metal, and especially pitting, is decreased.

It is evident that while the deposition of colloids is selective in that the deposits are heaviest where solution tends to be most rapid, yet deposition takes place to a certain extent at all points where pickling is taking place. Therefore, it follows that if colloidal addition agents are used in too large amounts, solution of metal will be retarded at all points and the pickling operation will be slowed down. This is probably the basis of the reports made by certain enamelers from time to time that the use of addition agents kills the action of the acid.[1] They must be used with judgment, if at all. This retardation is most liable to be noted in cases where addition agents are employed without taking advantage of the opportunity to increase the strength of the acid.

[1] Bur. Stand., *Tech. Paper*, No. 165, pp. 12.

Effect of Electric Current

Pickling can be conducted with the use of the electric current. The effect varies according to whether the ware is made the anode or the cathode.

Anode Pickling When the ware is made the anode, the effect of the electric current is simply to accelerate the processes that take place in straight acid pickling. That is, the pickling consists essentially of the solution of a thin layer of iron beneath the scale with evolution of hydrogen. In that the current accelerates the action of the acid and assists in the rapid solution of a very thin layer of iron with copious evolution of hydrogen, it assists in producing efficient pickling.

Cathode Pickling When the ware is made the cathode and use is made of an insoluble anode, the whole pickling operation is supposed to be reversed. The flow of the current is against the solution pressure of the iron and, therefore, the solution of metal is supposed to be stopped. The acid is electrolyzed and hydrogen is deposited on the ware. This hydrogen is supposed to reduce the oxide scale to ferrous sulphate which goes into solution.

Some points in this theoretically beautiful process are questionable. It is doubtful whether the currents ordinarily used entirely stop the solution of metal and it is still more doubtful whether any great amount of iron oxide is reduced to ferrous sulphate by the action of hydrogen.

While various modifications of these two primary methods of electrolytic pickling have been proposed and numerous processes have been patented, the fact is that, notwithstanding some of the obvious advantages, electrolytic pickling has attained little commercial importance.

Absorption of Hydrogen

It is well known that hydrogen is absorbed by metals during pickling. As noted by Treischel,[1] this hydrogen causes blisters during the enameling operation. Treischel recommended the use of dilute acid solutions, 3%, to cut down the amount of hydrogen absorption. The objection to this course is that such weak acid solutions pickle slowly and, therefore, inefficiently. An optional course is to use a strong acid pickling bath, which will result in the absorption of considerable hydrogen, and then to immerse the pickled ware for a few minutes in a boiling hot water washing bath. This serves practically to free the ware of hydrogen. It is an old trick in preparing metals for plating but does not seem to be so well known in the enameling industry.

[1] C. C. Treischel, *Jour. Amer. Ceram. Soc.*, **2**, 744 (1919).

Summary

1. Efficient pickling depends upon the solution of a very thin layer of iron directly beneath the scale, rapidly and with copious evolution of hydrogen.

2. Since the rate of pickling is proportional to the percentage of acid present multiplied by the per cent of the acid that is ionized, with the rate at which the ions move as a modifying factor, the most effective concentrations of acid lie between 15 and 20%.

3. Heating acid solutions reduces their viscosity and renders the particles more mobile, thus increasing the activity of the solutions.

4. Sulphuric acid is cheaper in first cost than hydrochloric acid, but the latter acts more rapidly and the pickling is completed with less solution of iron.

5. Additions of small amounts of common salt (sodium chloride) have a marked effect on increasing the rate of pickling of sulphuric acid baths. This is due to the formation of a corresponding amount of hydrochloric acid.

6. The chief action of addition agents is to reduce the amount of acid vapor in the fumes from pickling vats and thus permit the use of highly efficient concentrations of acid (between 15 and 20%).

7. Hydrogen absorbed by metals during pickling may be largely removed by immersing the metal in boiling hot water for a few minutes.

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GAS-FIRED ENAMELING FURNACES FOR CAST-IRON[1]

By Henry L. Read

ABSTRACT

A comparison is made of gas fired and electrically heated glass, enamel ovens. Description of equipment, data on output fuel costs, and upkeep are given.

Introduction

Some time ago a company making cast-iron bath tubs, lavatories, and miscellaneous "small ware," became curious to know whether the enamel furnace operating costs could not be improved. At that period a large number of electric resistance furnaces of a standard type were in use in the plant turning out an excellent grade of work. There were complaints, however, that the fuel bills seemed rather large and that occasional shut downs for repairs were necessary. The latter were expensive particularly because of the loss of production for four or five days while cooling off and reheating. After more than two years' use of the electric equipment, the company invited a well-known furnace manufacturer to provide something better.

There were five fuels commercially obtainable in that locality which have been successfully used for the type of work in question: coal or coke, oil, producer gas, electricity, and city gas. Since the choice of fuel is so closely connected with the kind of furnace in which it may be employed, a list is given below covering this subject for the product under consideration.

For coal or coke: muffle furnaces
For oil: muffle furnaces or intermittent furnaces
For producer gas: muffle, intermittent, or semimuffle furnaces
For electricity: Directly-heated furnaces with resistance elements along walls and arch and below hearth
For city gas: intermittent or semimuffle furnaces

The methods of operating these furnaces are well known and need no description other than the remark that with intermittent furnaces, the burners are turned off while the ware is in the working chamber and relighted while the ware is outside being sprayed, inspected, etc. These facts make the intermittent furnace unsuitable for the present work because of continual delays that are experienced while the operator is waiting for the empty furnace to come up to temperature, frequently with a sprayed tub ready to be returned for a reheat. Modern

[1] Received June 5, 1925.

handling methods have greatly diminished the serviceability of the intermittent furnace by cutting out the delays formerly experienced during which the furnace could be reheated. The choice was therefore narrowed down except for electricity to muffle and semimuffle furnaces.

Muffle versus Semimuffle Furnaces

Other things being equal, the semimuffle furnaces are clearly more economical of heat, and of much greater importance, far less apt to get out of order. In the older types of muffles of fire clay, cracks would often develop after short periods of operation. Sometimes damage would occur from careless firing. Their life was generally short and the furnaces were frequently down for repairs. These serious objections have been largely overcome by muffles of high grade refractories which are naturally of much greater initial cost. Two years' life of a muffle is now a fair figure but the fundamental weakness is still there: the expensive muffle must be replaced at times. Consequently with similar general construction a muffle furnace is more costly to build and keep up than a semimuffle. On the other hand, a muffle insures (at least while it is new) a working chamber atmosphere entirely free of dirt and with but a small amount of products of combustion. Cheaper fuels such as coal or oil may therefore be burned since the ware will not be injured. Thus although the thermal efficiency of a muffle furnace is always lower for the same conditions than that of a semimuffle, the actual fuel cost on the muffle may be less because more refined fuels are required for the semimuffle. Therefore, the decision as to the furnace is governed not only by the cost of fuel but also by repair expense on the furnace.

To give an idea of what had been done previously, the following table was submitted:

Question of Fuel Economy

As to the amount of oil to operate a suitable muffle furnace for the required work, the average seems to be around 13 gallons per hour with a minimum of 11 when turning out 60 tubs per day weighing 12,600 pounds. A low figure for oil per 100 pounds is therefore 2.1 gallons. In addition to the oil, however, the operating cost must include the price of a muffle every two years, approximately $1,000. This last statement assumes the muffles to be made of modern high grade refractories, not fire clay.

With regard to coal and coke, there is no question that a given number of heat units may be obtained from them more cheaply than from other fuels, but the lack of easy control over coal-fired muffle furnaces, the extra labor to handle them, and the more rapid deterioration of the muffles are every day causing more plants to go to oil, electricity, or gas. Loss of production on coal-fired furnaces due to

Operation	Temp.	Fuel	Firing equipment	Hrs. per day	Output per day	Fuel consumption	Unit fuel consumption	Remarks
(1) Enameling c. i. bath tubs. Fce. 8½'w.×8½'d.×4½'h. to spring (inside) semimuffle	1700°F	Nat. gas 950 B.t.u.	S.C. burners C.U. recuperators	24	60 tubs = 12600 lbs. per 24 hrs.	26700 cu. ft. per 24 hrs.	212 cu. ft. per 100 lbs.	Each tub charged cold once and reheated from 1000 to 1600°F 2½ times average. Sunday holding consumption of about 7000 cu. ft. total not included.
(2) Enameling miscel. c.i. Fce. 8'w.×6½'d.×3' h. to spring (inside) semimuffle	1600°F	City gas 500 B.t.u	S.C. burners	24	11400 lbs. small ware per 24 hrs.	37700 cu. ft. per 24 hrs.	331 cu. ft. per 100 lbs.	All ware heated once from 50 to 1600°F. Half of ware reheated twice from 1100 to 1600°F. Half reheated once from 1100 to 1600°F. Sunday holding not included 8000 cu. ft.
(3) Enameling c.i. bath tubs. Dimensions 7'w.×8'd.×3'h. to crown (inside)	1700°F	Electricity	G.E. heating elements	24	60 to 65 tubs =12600 to 13650 lbs. per 24 hrs.	3420 to 3900 KWH per 24 hrs.	57 to 60 KWH per tub =28.1 per 100 lbs. approx.	Same operation as (1). $1800 worth of heating elements must be replaced about every 2 years. Owner claims this is good operation.
(4) Enameling c.i. sinks. Fce. 8'6" w.×8'd.×6'3" h. to spring. Semimuffle.	1600°F	Producer gas 150 B.t.u. clean	S.C. burners	24	17100 lbs. per 24 hrs.	9070 cu. ft. per hr.	1273 cu. ft. per 100 lbs.	Each sink heated once from cold to 1600°F and twice from 1000 to 1600°F. Fces were old. Data is from 7 hr. test and does not include Sunday or lost time holding.

delays while they are regaining desired temperatures, for example, after cleaning fires, is one of their greatest weaknesses which is almost never experienced with more refined fuels. Coal was consequently eliminated from consideration.

Furnace and Fuel Adopted

After study of all the factors, city gas was recommended and adopted in this particular case. The furnace design employed is shown in Figs. 1 and 2.

The purposes kept in mind when this appliance was designed were:

1. To make it the most economical furnace in regard to fuel consumption per unit of output.
2. To make it compact.
3. To insure maximum uniformity of temperature in all parts of the actual working zone.
4. To maintain constant temperatures and furnace atmosphere regardless of the rate of working.
5. To eliminate the danger of dirt falling on the tubs.
6. In general to bring about the production of a superior grade of ware at a lower cost than could be obtained from the customer's existing electric furnaces which were admitted to be the most completely satisfactory equipment for firing enamel on cast-iron bath tubs hitherto available.

The means used to obtain these results are shown in the illustrations.

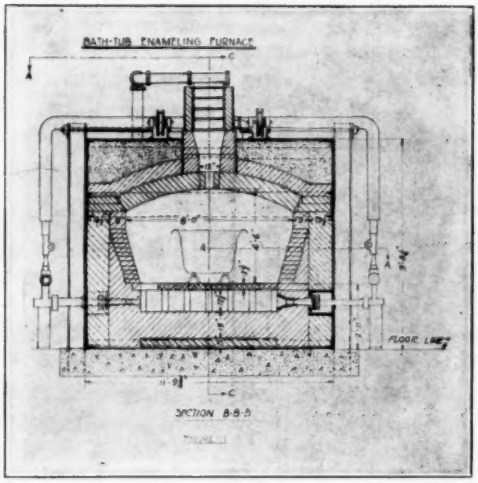

FIG. 1.

1. Economy was effected by unusually heavy insulation with Sil-O-Cel bricks and powder, 9 and 13½ inches thick; by welding the sheet steel casing to reduce internal air circulation; by the installation of standard metallic Combustion Utilities recuperators on top of the arch whereby the air for combustion was preheated approximately to 650°F and by the use of Surface Combustion low pressure velocity burners for city gas of 535 B.t.u. heat content.

2. Compactness was brought about by keeping all projecting parts such as burners, piping, door, counterweights, etc., either inside suitable recesses in the casing or behind sheet steel guards. Castings were as far as possible dispensed with.

3. Much study was involved in maintaining uniformity in temperature, resulting in the side walls being tapered as shown, corresponding to the general outlines of the tub. As will be readily appreciated, the rims being relatively light will heat more rapidly than the bottoms and therefore tend to become overheated when the furnace is run at a temperature slightly above that required in the ware. This latter condition normally exists in operation in order to make sufficiently rapid production. When the tubs are first heated from cold, the red ground coat on the rims is in danger of burning and blistering unless overheating is prevented. The scheme of keeping the brick work at an approximately uniform distance from the iron was evolved to overcome that danger. In conjunction with well-developed circulation of flue gases below the hearth, the design showed excellent results in regard to temperature distribution.

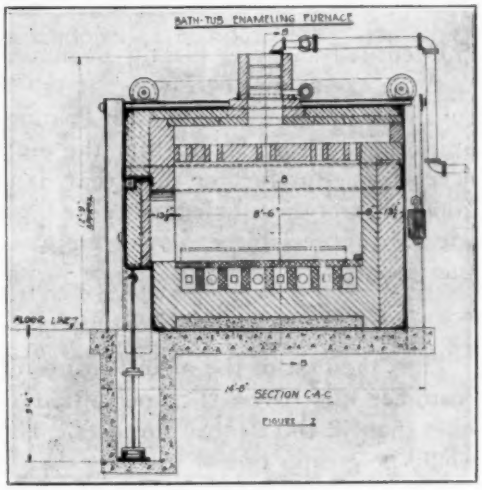

FIG. 2.

4. To meet the requirements there was evolved a satisfactory combination of the Surface Combustion automatic proportioning apparatus with the Bristol-Fuller valve and Leeds and Northrup pyrometer controller.

5. The question of particles of furnace cement, brick, etc., or occasionally unburned carbon, getting into the white enamel during the firing, was considered a most serious one. To get around it, the door was constructed so that it was lowered to open, the converse of ordinary procedure in which the door is closed by being lowered. Thus trouble from little pieces falling from the door upon the work as the latter was inserted into or withdrawn from the heating chamber was avoided. Furthermore, the furnace interior was covered with a special "Bristol" glaze which protected the ware from dirt particularly during the firing. The danger of unburned carbon was removed by setting the inspirator adjustment so as to maintain always an excess of oxygen. Perfect mixing and firing was provided for by the Venturi throats and the tunnels at the burner outlets.

6. It was felt that if the five points previously mentioned were thoroughly covered, superiority of ware necessarily would follow pro-

vided that sound principles of furnace construction were followed. It is gratifying to note that these expectations were entirely fulfilled.

Prevention of Reduction

A certain amount of prejudice at the start had to be overcome because of the fear that in the absence of a muffle black specks of unburned carbon from the fuel might settle on the ware in the furnace and so ruin its appearance. Likewise there was the danger of burning the ground coat if the atmosphere through some mischance should become reducing.

Eventually it was clearly demonstrated that with around 50% or more excess air there was not the slightest danger of spoiling the tubs from chemical reactions or floating dirt specks. Even the loudest objector admitted finally that the muffle had been proved to be unnecessary. But further than that, it ultimately was shown that the appearance of the tubs heated in the presence of products of combustion with an appreciable excess of air was markedly superior to that of tubs from the electric resistance furnaces.

Cost of Operating

Thus the first of the main features of the furnace of interest to the customer was covered: namely, that the work could be done better in it than in the electric furnaces. The second was whether the cost would be greater or less with gas than electricity. On this point, only cost data kept over a considerable period are of real meaning, but the preliminary figures obtained are interesting. It was found that roughly 70 tubs weighing 220 pounds each per 24-hour day can be made in this furnace with a consumption of about 42,000 cubic feet of gas. This is equivalent to 600 cubic feet per tub or 273 cubic feet per 100 pounds. In addition about 8,000 cubic feet are needed to heat the furnace after the week-end shut down. Allowing for the various operating delays, the furnace produces in one week 365 tubs weighing 220 pounds each on 240,000 cubic feet.

The cost of electric enameling includes the wages of a switchboard operator 24 hours a day, as well as approximately 50 kilowatt hours per tub. It does not, however, allow for rejections but refers merely to the total number of tubs of the specified size put through the furnace as does the figure for the gas furnace.

Rejections

On the question of rejections, the records showed that there were certainly no more defective tubs from the gas furnace than from the electrics and probably not as many.

Labor

Labor for operating the two types was the same except that one switchboard operator for the entire battery of electric furnaces was required at all times. No man corresponding to him is necessary on any number of gas furnaces.

Repairs

As to repairs, the gas furnace shows a great superiority. The electric furnaces give continual trouble on this score, involving not only actual labor and material for each breakdown (a comparatively small part of the expense usually), but also the loss of production for about five days and the expenditure of energy to heat the furnace up again to working temperature. The original electric furnaces at the plant were objectionable because the resistors were set in the side walls where they frequently were broken by contact with the fork carrying tubs into and out of the furnace. To get around this, there were built, with the advice and assistance of the industrial heating department of a large maker of electric appliances, a number of improved furnaces that were supposed to be the last word in perfection. The resistors in the new furnaces were placed in the arch and below the hearth for protection. Unfortunately the altered design has not shown any reduction in the frequency and cost of repairs.

Size of Ware

Up to this time only one size of tub has been referred to: the one which was 220 pounds and 5 feet long. It should be understood also that all kinds of tubs were successfully heated in the gas furnace including those $6\frac{1}{2}$ feet long weighing over 400 pounds and having aprons on one side and one end. These last are most difficult to heat properly because of the great unevenness of the distribution of the weight.

Output

Although all the data collected thus far led to the belief that the overall cost of heating by gas would be well under the cost with electricity, the extremely important question of capacity and rate of heating in the gas furnace still remained open. The output of 70 tubs of 220 pounds each per day at 1790°F previously mentioned was as fast as the crews could be made to work on steady production with either type under present conditions, but there was always the possibility that labor-saving devices might enable the men to increase the output. Furthermore, improved enamels might require a somewhat

higher temperature than is now employed. With these facts in mind the electric furnaces had been built and subjected to very special speed tests which it was necessary that the gas furnace should at least equal before it could be considered satisfactory. Consequently, arrangements were made to try out the gas furnace for rapidity of working just as the electric furnaces were tested.

Going over the records it was found that the best performance of any of the electrics was an output at the rate of 35 tubs in 8 hours at 1820°F. This is equivalent to one tub every 13 minutes and 42.8 seconds. Under corresponding conditions the gas furnace averaged one tub in 13 minutes and 22.5 seconds at 1825°F. The capacity of the gas furnace was therefore superior to that of the electrics.

Heat Balance

A heat balance of the gas furnace follows:

Heat absorbed in work	28.3%	Heat lost in the flue gases leaving open door	1.6%
Heat lost in wall radiation	14.1%	Heat given up to air in recuperator	30.9%
Heat lost in open door radiation	2.4%		
Heat lost in flue gases leaving recuperator	22.7%	Total	100.0%

The tests described in the foregoing have clearly shown that the Surface Combustion gas furnace has marked advantages over the electric furnaces at the plant referred to in regard to quality of product, reserve capacity, and overall cost of the firing operation per unit of output. An order recently given by the user for four more similar furnaces is sufficient proof of this.

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DEFECTS IN ENAMEL DUE TO CAST IRON

By A. Malinovszky

ABSTRACT

Microphotographic examination of iron on which enamel has pinholed, blistered, and come perfect are cited as evidence that carbon is practically the only agent in cast iron causing blistering and pinholing and that it is the condition and not the presence of carbon that causes these defects.

The real cause of pinholing and blistering is a question that frequently confronts the enamelist and each time that this trouble occurs, the conditions seem to vary. However, the solution for each repetition of this trouble seems to narrow down to quite a small range of causes. Positive answers to many of the questions concerning pinholing and blistering will be a great accomplishment.

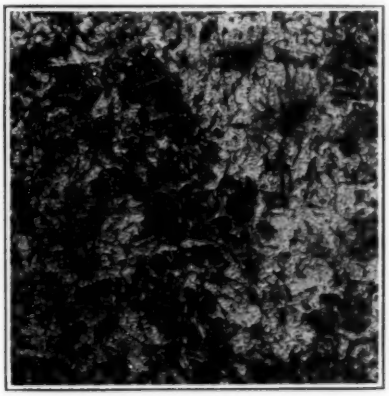

FIG. 1.—100×.

Broadly considering the cause of blistering and pinholing in enameled ware, we find many factors which can be roughly grouped into three classes; (1) defects due to raw materials or volatilized matters in ground coat or enamel, (2) those resulting from working conditions, and (3) from the iron.

Naming briefly the causes of our troubles in emameling sanitary cast-iron ware, we have:

1. Dirty iron or uneven thickness, or iron containing slag.
2. Iron containing high phosphor, sulphur, manganese, and carbons, especially when the latter is in segregated forms.
3. Heavy or overfired ground coat.
4. Improperly dried ground coat.
5. Too rapidly applied enamel or "pilling" it in spots.
6. Foreign matters in the enamel, or wrongly compounded.
7. Underfused enamel, ground coat, or furnace gases.

Effect of Carbon Content in Iron

For a period of several months an accurate check was kept on each raw material and record kept as to the results obtained after the slightest changes in materials, equipment, working conditions, and methods were made. All known results obtained by different experts were used in experiments with varied results. Samples from castings and microphotographs were sent to different well known metallurgists. The final answer resulting from these studies was that the trouble lay in the uncertain carbon content in the iron.

[1] Received April 6, 1926.

[1] The letters in the microphotographs designate the following: P, pearlite; S, steatite; F, ferrite; MnS, manganese sulphide; G, graphite; and M, martensite.

Reduction Due to Carbon and Iron

Tin oxide and antimony oxide used in the enamel mix are easily reduced by carbon. The oxidizing action of the iron during the enameling process forms carbon gases. These not only are liable to produce blisters but also to reduce the opacifying agents so that they appear as black specks in the enamel.

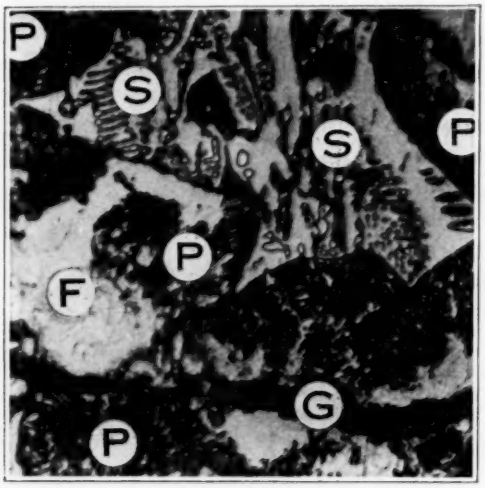

FIG. 2.—1000×.

The sulphur, phosphor, manganese, and silicon contents of the iron were varied in countless proportions with no avail. Steel scrap and different cokes were experimented with and no satisfactory results were obtained. It was not until an entirely different pig iron was used that the carbon content of the iron was brought under complete control. A noticeable difference was observed in the working of the ware.

In the many heating and cooling processes the carbon rapidly changes in chemical and physical properties. Pinholing and blistering may occur due to the volume changes of gases contained and formed in the iron.

How to Keep Carbon Low

The chemical affinity of carbon for iron is very great but iron discharged rapidly from a cupola and at proper temperatures will not be anywhere near its saturation point in carbon. Iron allowed to remain in a cupola for a long time at low temperatures will contain carbon close to its saturation limit. Iron having been for a considerable time in contact with the cupola coke will naturally have absorbed its limit of carbon. The natural tendency will be for this carbon to be present in several different crystal forms many of which are undesirable and injurious.

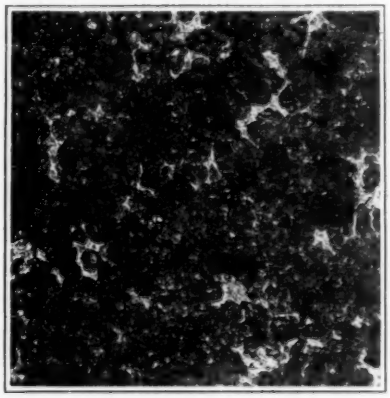

FIG. 3.—100×.

Pig irons must be mixed in certain proportion and with scrap before good results can be obtained. This mixing is necessary because some irons have greater affinity for carbon in the cupola than have others.

The constitution and properties of iron used in enameling are far more difficult to understand than are those of steel. The difficulty of predicting from an analysis the effect of any change in composition of cast iron is far greater. A change in any of the constituents of cast iron is liable to effect changes in several other ingredients.

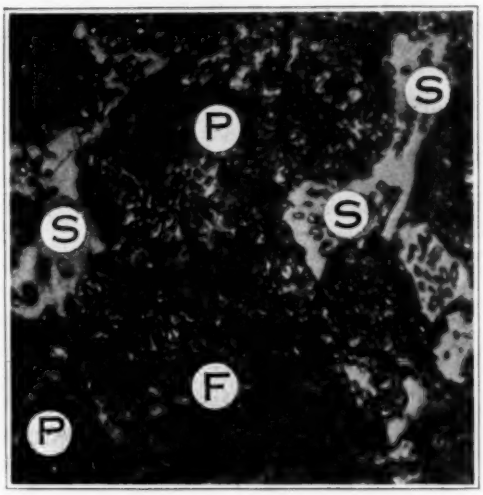

FIG. 4.—1000×.

Value of Chemical Analysis of Cast Iron

Two different cast irons having almost identically the same chemical analysis when enameled with the same ground coat and enamel in the same temperature will give different results. Cast irons with extreme differences in their constituents have given equally good results. Chemical analysis will not always show the causes of pinholing and blistering. More stress should be placed on the state of the elements in cast iron rather than their proportion as shown by a chemical analysis.

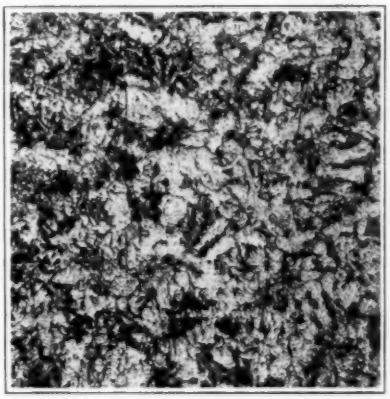

FIG. 5.—100×.

The microphotographs of Figs. 1, 2, 3, and 4 were all taken from one specimen from a bath tub which was badly blistered or broken out. Figures 1 and 2 were both taken from the same end of the specimen; Figs. 3 and 4 were taken from the opposite end of the sample where no blisters were present on the enameled surface. This sample shows a different structural composition at the two ends. Figure 1, 100×, shows the general structure at one end. Figure 2, 1000×, same as Fig. 1, shows detail of the materials present, *i.e.*, steatite, graphite, pearlite, ferrite, and manganese sulphide.

Figures 3 and 4 show the general structure of the other end of the sample. Figure 3, 100×, shows no free ferrite, a smaller amount of graphite, and much more pearlite than the other end of the sample. Figure 4, 1000×, same as Fig. 3, shows a structure consisting almost wholly of pearlite and steatite with a small amount of graphite.

The above analysis of the sample is as follows:

Compounds Present

	Per cent		Per cent
Total carbon	3.245	Graphitic carbon	3.24
Graphitic carbon	2.808	Iron carbide	6.25
Combined carbon	.437	Manganese carbide	.32
Silicon	2.516	Iron phosphide	4.49
Manganese	.391	Iron silicide	7.53
Phosphor	.662	Manganese sulphide	.15
Sulphur	.055	Iron	78.02

Structural Composition

	Per cent		Per cent
Pearlite	52.56	Manganese sulphide	0.15
Steatite	2.62	Ferrite	37.87
Graphite	2.80		

Figures 5 and 6. This sample was cut out from the opposite end of a bath tub on which no blistering occurred during the enameling process. The sample shows the same structure to be present at both ends.

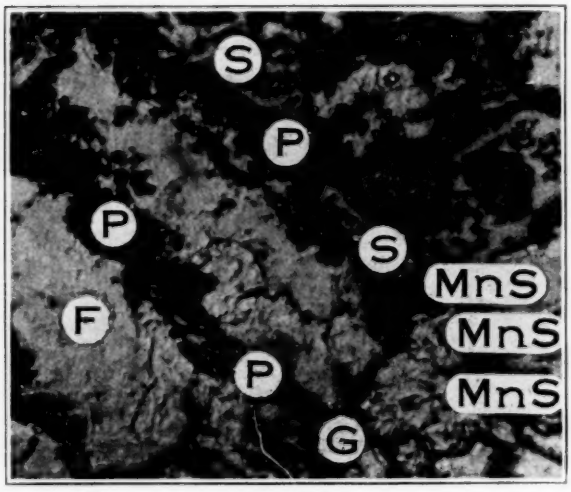

FIG. 6.—1000×.

The microphotograph, Fig. 5, 100×, shows the general distribution of materials. The microphotograph Fig. 6, 1000×, same as Fig. 5, shows under the microscope much less pearlite than the analysis would call for.

This sample has the following analysis:

Compounds Present

	Per cent		Per cent
Total carbon	3.191	Graphitic carbon	3.19
Graphitic carbon	2.808	Iron carbides	5.49
Combined carbon	.383	Manganese carbide	.25
Silicon	2.887	Iron phosphide	4.88
Manganese	.526	Iron silicide	8.66
Phosphide	.721	Manganese sulphide	.23
Sulphur	.088	Iron	77.30

Structural Composition

	Per cent		Per cent
Pearlite	45.92	Manganese sulphide	.23
Steatite	7.21	Ferrite	43.84
Graphite	2.80		

In Fig. 7, 1000×, the original pearlite areas were apparently changed to martensite. These areas, which appear dark in the photograph, are in reality yellow under the microscope. No blistering occurred when the enamel was applied to this iron.

Figure 8, 1000×, shows large areas of ferrite and more steatite than does Fig. 7. This sample was taken from a blistered sink.

Figure 9, 1000×, shows a slight trace of steatite. This sample was taken from a tub on which no trouble was experienced in enameling.

Figure 10, 1000×, shows large ferrite areas and less graphite. This sample was taken from a bath tub on which the enamel showed pinholing and in patches looked pitted.

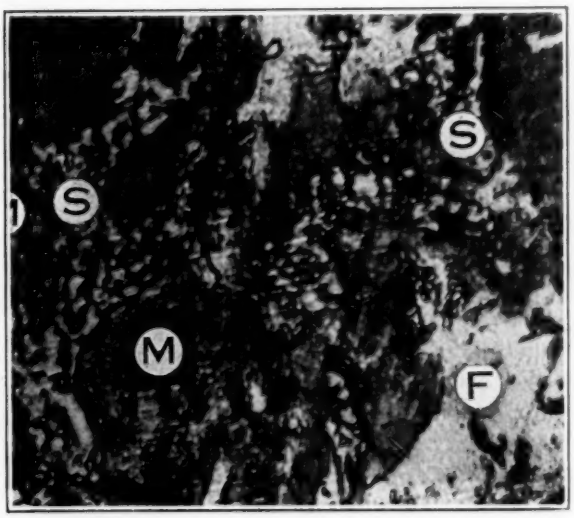

FIG. 7.—1000×.

Figure 11, 1000×. Martensite is very prominent. This sample was taken from a bath tub which blistered so badly as to leave the enamel full of minute pinholes.

Figure 12, 1000×. The graphite occurs in entirely different form than it does in the other samples. This sample was taken from a bath tub where blistering was prominent in patches.

Figures 13, 14, and 15 were taken from a bath tub which was covered with large and small pinholes. These samples as seen in the microphotographs possess a most remarkable structure. They appear to consist entirely of straight ferrites with slag veinlets. This condition is found to be constant throughout the sample.

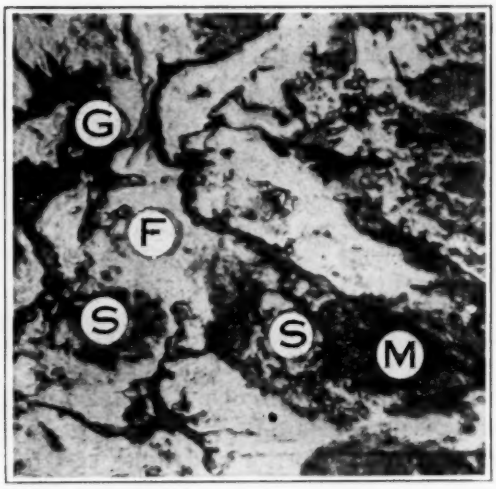

FIG. 8.—1000×.

There is no trace of the usual structural elements of cast iron as used for enameling; that is, pearlite, steatite, and graphite, etc. Some of the black spots are silicate material and contain what apparently are areas of graphite.

Figure 13, 100×, is an unetched sample showing the structure of the sample and the distribution of the slag veinlets. This sample was taken from the bottom of a bath tub which was covered with pinholes.

Figure 14, 100×, unetched, shows a structure of black spots on the surface. This figure has a very unusual appearance. No reason can be seen for the structure. The tub from which this specimen was taken had been subjected to repeated heating in an effort to patch both large and small groups of blisters or "glass eyes" which occurred during the enameling operation. Some of these blisters were black.

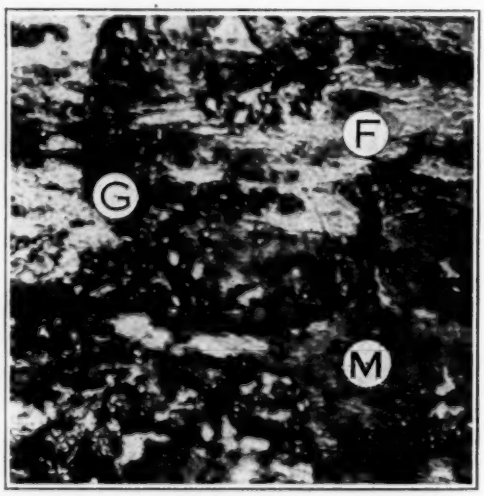

FIG. 9.—1000×.

The numerous heatings (16 times) have developed brittleness of the iron which under the microscope has the appearance of an over-fired structure.

Figure 15, 1000×, which was etched with HNO_3 in alcohol shows details of ferrite and veins of slag material. The slag under the micro-

scope seems to be composed of two different materials having slightly different colors. The graphite spots also are noticeable owing to their odd form.

A very prominent metallurgist who examined these photos said: "In my experience, I have never run across a specimen in any way similar to this one."

Figure 16, 1000×, is a photo of one of the blotches where the enamel broke out very badly. Every metallurgist who has examined this photo claims he cannot comprehend it.

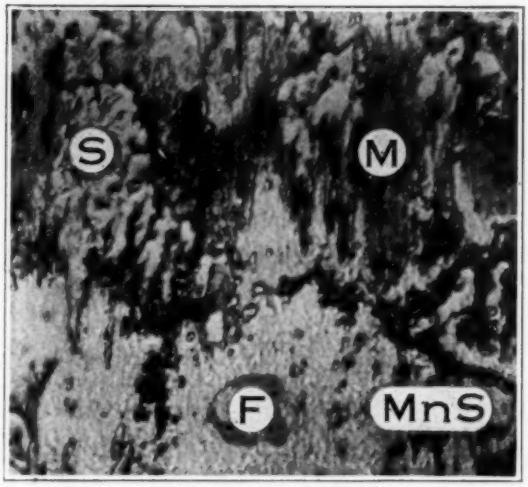

FIG. 10.—1000×.

In reviewing the preceding microphotographs and comparing them with the results obtained from these samples during the enameling operation it is very difficult to draw any definite conclusion as to the cause of blistering in enamel on cast iron merely by comparing one photo with another. In Figs. 13 and 14 the cause of the blistering and pinholing of the enamel is shown very clearly.

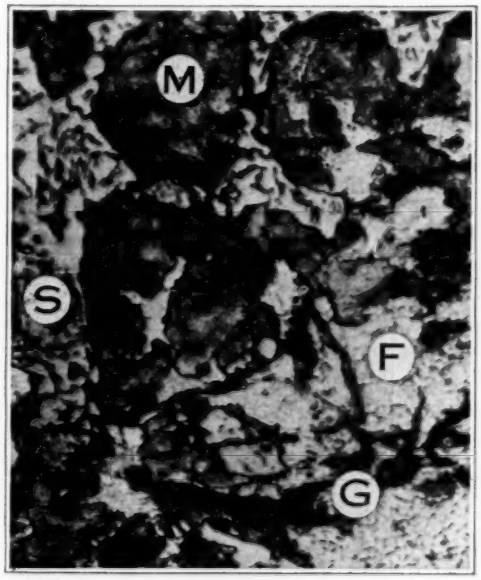

FIG. 11.—1000×.

Enamel Defects Due to Condition of Carbon

It is my belief that pinholing and blistering are due to the condition of the carbon in the iron and not due (as many insist) to the presence of carbon.

Cast iron cannot be considered a simple metal or alloy. It is an aggregated compound of various structures. Even the

slightest change in the proportion of the compounds in the pig will, upon melting, change the character of the iron so much that it becomes a product of different qualities and with different expansions.

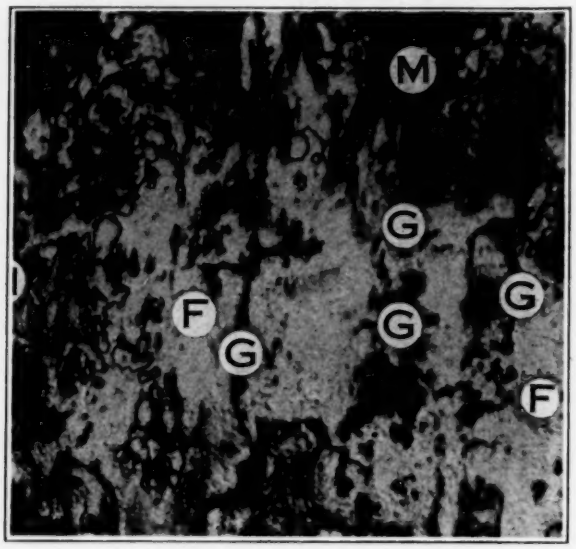

FIG. 12.—1000×.

What may seem to be a slight chemical change of the primary mixture of the iron, may be the fundamental cause of an enamel chipping, crazing, or blistering when it is applied to the ware.

Effect of Other Constituents

If blistering and pinholing of enamel in cast iron are caused by the iron this is the only explanation so far at hand. We cannot overlook the influence on the enamel of phosphor, sulphur, manganese, and other impurities collecting into localized groups, nor that of manganese sulphide known to the foundrymen as "hot spot." Many "hot spots" have been found so extremely hard that no tool will cut them and upon application of enamel a craze will appear resembling a spider web. The occurrences of this phenomenon are more frequent in bath tubs than in similar castings.

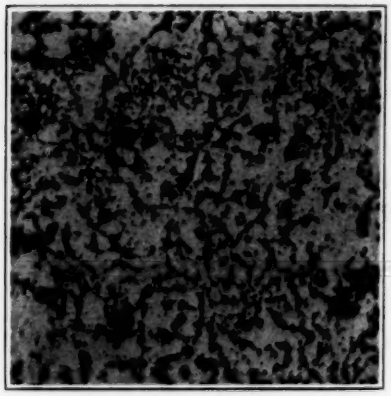

FIG. 13.—100×.

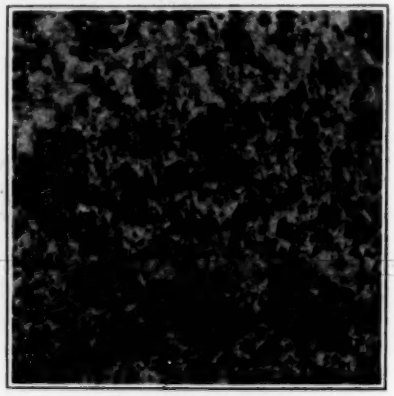

FIG. 14.—100×.

High silicon content in an iron causes considerable damage since it precipitates the carbon, driving it out of combination into a graphite form. The iron is thus changed from ferrite and pearlite into ferrite and graphite. This is illustrated in Figs. 13 and 14.

FIG. 15.—1000×.

The microphotographs have shown no pearlite to be present in cast irons having high silicon and low sulphur and manganese. Silicon in cast iron seems to prevent the formation of iron carbides and promotes ferrite and graphite only.

The foregoing conclusions have been previously advanced in slightly different aspects by the author in 1917, when, working in conjunction with Mr. Hathaway, metallurgist, an article illustrated by lantern slides was presented before the American Chemical Society Local Section of St. Louis, Mo. A paper by the author[1] drew attention to the variation of the carbon in the castings analyzed before and after the ware was enameled.

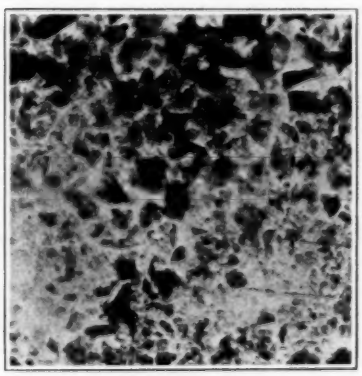

FIG. 16.—1000×.

It would seem to be convincing testimony that carbon is practically the only agent in cast iron that will cause blistering and pinholing due to its continuous transformation from one state into another during the enameling process.

WASHINGTON IRON WORKS
LOS ANGELES, CALIF.

[1] A. Malinovszky, "Enameling Defects Due to Cast Iron," *Jour. Amer. Ceram. Soc.*, 8 [1], 72–78 (1925).

SEVERAL GAS EXPANSION POROSIMETERS[1]

By A. Ernest MacGee[2]

ABSTRACT

A relatively inexpensive and simple brick porosimeter and its operation is described. A convenient indirect and a direct reading porosimeter for small test pieces is described. The direct reading porosimeter reduces calculations to the minimum.

Gas Expansion Method

In an effort to overcome the objections inherent in the liquid absorption method, Washburn and Bunting[3] developed several types of apparatus which make use of the principle of gas expansion for determining porosity. In this method, a gas instead of a liquid is used to fill the pores of the sample, its amount being determined by measuring the change in pressure which accompanied a definite increase in its volume. From the pressure differences obtained by any one of several general procedures, it is possible to calculate either the solid or the pore volume of the test piece. Bulk volume is determined by direct measurement or by liquid displacement. The gas expansion method yields very accurate results even for bodies of low porosity and exceedingly fine pores.

Although Washburn and Bunting developed an apparatus of the McLeod-Gauge type, it remained for Navias[4] to arrange this type of apparatus into a sturdy convenient form in which the pore volume is read direct. However, the bulk volume must be determined in some second apparatus, an obvious disadvantage.

The Direct Reading Porosimeter

In the following apparatus based upon the principle of gas expansion, both the bulk and solid volumes are directly read from burettes. This simplifies the calculation to a single subtraction and division, thus greatly facilitating the ease with which a complete porosity and apparent specific gravity determination can be carried out.

Figure 1 is a diagrammatic sketch of the apparatus. The sample container, B, is of exactly 100 cc internal volume from A to Z, (being about $4\frac{3}{4}$ in. long and $1\frac{1}{4}$ in. in internal diameter). The expansion

[1] Published by permission of the Director, U. S. Bureau of Mines. Received July 26, 1926.

[2] Coöperative Research Engineer, U. S. Bureau of Mines.

[3] E. W. Washburn and E. N. Bunting, "Porosity VI. Determination of Porosity by the Method of Gas Expansion," *Jour. Amer. Ceram. Soc.*, **5**, 112 (1922); "Porosity VII. The Determination of the Porosity of Highly Vitrified Bodies," *Jour. Amer. Ceram. Soc.*, **5**, 527 (1922).

[4] L. Navias, "Metal Porosimeter for Determining the Pore Volume of Highly Vitrified Ware," *Jour. Amer. Ceram. Soc.*, **8**, 816 (1925).

chamber, *C*, is an ordinary 100 cc burette, the 100 cc mark being at *Z*. *D* is a burette of about 200 cc capacity. Only the lower portion of this burette need be calibrated, the 100 cc mark being at *F*. *E* is an ordinary meter stick calibrated in millimeters for measuring differences of pressure in *C* and *D*. *G* is a flexible metal covered rubber tube. It is necessary that the tube be metal covered because of excessive error caused in stretching of the rubber tube by the mercury which is essential to the use of this type of apparatus.

Theory of Operation Assume that mercury is standing in the burette *C*, up to the point *Z*. On closing the stop-cock, there is enclosed in *B* exactly 100 cc of air. If this 100 cc of air be expanded until it is 200 cc by allowing mercury to run out of *C*, the difference in pressure between the mercury column in *C* and *D* will be one-half of atmospheric. Obviously, if any volume of air in *B* is expanded until the pressure difference of the mercury column in *C* and *D* is one-half of atmospheric, the volume of air in cubic centimeters contained in *C* will be equal to the volume of air originally in *B*, that is, halving of the pressure doubles the volume.

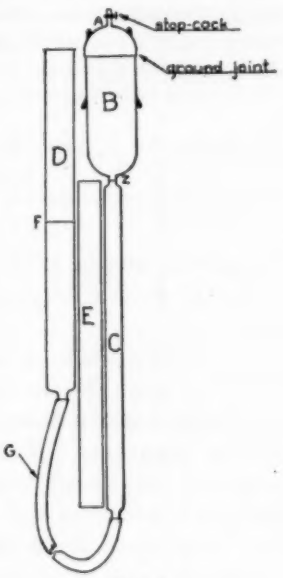

FIG. 1.

With a sample in place in *B*, a certain portion of the total volume is occupied by the solid part of the sample. Thus, setting the mercury at *Z* and closing the stop-cock, an unknown volume of air is enclosed in *B*. On expanding this volume until the pressure is one-half of atmospheric, the volume of air in *C* is the air volume in *B* unoccupied by solid material. By subtracting this volume from 100 (the total volume of *B*), the solid volume of the sample is obtained. That is, if there were 40 cc of air in *C*, the solid volume would be 100 minus 40, or 60. However, with the 100 mark at *Z*, 40 cc of air would be in *C* when the reading of the burette was 60. Thus, the burette reading on *C* is the solid volume of the test piece.

Assume sufficient mercury is placed in the apparatus to cause the levels to be at *F* and *Z* when they are held parallel. With the previously mentioned sample in *B*, its bulk volume is determined by allowing mercury to flow from *D* until *B* is filled to the point *A*. Assume that

20 cc ran out of D. Then 100 minus 20, or 80 is the bulk volume of the sample. With the calibration of D beginning with 100 at F, the burette would read 80 when 20 cc of mercury had run out. Thus the burette reading on D is the bulk volume of the test piece. On subtracting the solid volume from the bulk volume and dividing by the bulk volume, the percentage porosity is obtained by multiplying by 100.

Determining of Porosity Sufficient dry and clean mercury having been previously placed in the apparatus to cause the levels to stand at Z and F, the sample is placed in B and the cover clamped tight by means of rubber bands.

(1) With the stop-cock open, D is elevated until the mercury level in C stands at Z, after which the stop-cock is closed.

(2) By lowering D, mercury is allowed to run out of C until the pressure difference between C and D is one-half of atmospheric as read on E.

(3) The burette C is read, this reading being the solid volume, s, of the test piece.

(4) The stop-cock is opened and D is elevated until the mercury level in B stands at A.

(5) The burette, D, is read, this reading being the bulk volume, b, of the test piece.

(6) Porosity in per cent $= \frac{b-s}{b} \times 100$

If apparent specific gravity is desired, the solid volume, b, is divided into the dry weight, w, of the test piece, the quotient being the value sought.

Accuracy The precision attainable with this method depends largely upon the refinement of construction of the apparatus. The apparatus herein described was not designed to give the maximum attainable accuracy. Rather, it was so constructed as to employ rectangular test pieces which could later be used in cross-breaking strength or other tests and to give quite reliable values for all ceramic bodies, other than those of porosities below about 5%. In order to determine the extent to which results could be duplicated from time to time, porosity was determined on the same test piece at four different times with the following results:

Test	1	2	3	4
Per cent porosity	35.0	35.3	35.2	35.3

Accuracy can be increased by employing test pieces which fit snugly into the apparatus and by refining the calibration and size of the burettes, C and D, as well as the method of obtaining the differences in pressure. Like all of the air-expansion methods, slightly larger porosities are usually obtained than by the liquid absorption method.

In order to obtain a comparison of the results rendered by the direct reading, indirect, and water methods, the porosity of a number

of test pieces was determined by each of these methods. The results are tabulated in Table 1.

TABLE I

PER CENT POROSITY

Test piece	Direct reading	Indirect	Water
1	34.5	34.3	31.9
2	35.0	34.9	32.2
3	39.9	39.2	37.2
4	33.7	31.8	32.1

The Indirect Method

An apparatus was designed to operate on the general principle in which the free air space is calculated after measuring the fall in pressure which accompanies a definite increase in volume. This type of apparatus was constructed in order that porosity and apparent specific gravity could be accurately and conveniently determined for test pieces of a wide range in size and shape. This apparatus was designed to carry a test piece 1 x 1 x 4 inches, a convenient size to make and a size which readily lends itself to other tests, including cross-breaking strength on a 3-inch span.

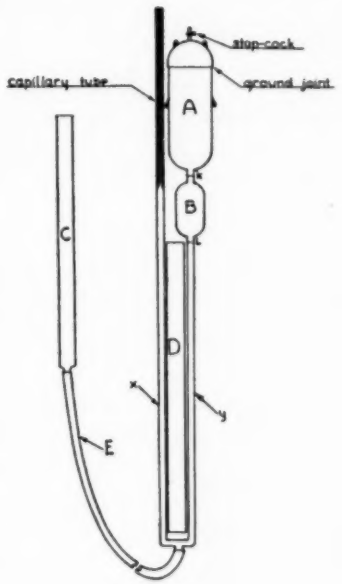

FIG. 2.

Description of Apparatus Figure 2 is a diagrammatic sketch of the indirect reading porosimeter. *A* is the sample container of any convenient volume up to the mark, *K*. In this particular apparatus, the volume of *A* is 145 cc, the cylinder being about 5 inches long and 1½ inches in diameter. This is a convenient size for carrying 1 x 1 x 4 inch test pieces and at the same time allowing for considerable oversize. *B* is an expansion bulb of any convenient volume from *K* to *L*. With a sample container of the volume mentioned above, about 50 cc is the proper volume of *B* in order to assure accuracy when a great variety of sizes in test pieces are likely to be encountered. *C* is a regular 200 cc burette calibrated into tenths. *D* is an ordinary meter stick. The open end manometer, *x* and *y*, is made of about 5 millimeter bore tubing. Beginning at a point just below *K*, the open end of *x* is made of fine capillary

tube. This is in order to avoid the use of a second stop-cock and at the same time to retain accuracy in the bulk volume measurement (as A is being filled with mercury, some would be running out of C into this manometer tube, thus making the reading on C too large). E is a metal covered rubber tube, metal being used to avoid stretching by the mercury employed in the apparatus.

Determining of Porosity Sufficient mercury having previously been placed in the apparatus to fill C to the zero mark when the mercury level stands at K, the sample is placed in A and the top fastened securely by means of rubber bands.

(1) With the stop-cock open, C is elevated until the mercury level in B stands at K.

(2) After closing the stop-cock, C is lowered until the mercury level in B stands at L.

(3) The pressure difference between x and y is read on D. The solid volume is calculated from this reading.

(4) After opening the stop-cock, C is elevated until the mercury level in A stands at the stop-cock.

(5) C is read. This reading subtracted from the total volume of A gives the bulk volume, v, of the test piece.

Calculating Solid Volume (1) The reading, R, of D (as determined under 3 above) is subtracted from the barometric pressure in order to obtain the pressure, p, after the expansion process described under 1 and 2 above.

$$\text{(2) Air space, } a, \text{ in } A = \frac{p \times B}{R}$$

B is the volume from K to L

$$\text{(3) Solid volume, } s, \text{ of test piece} = A - a$$

A is the volume from the stop-cock to K

$$\text{(4) Porosity in per cent} = \frac{v - s}{v} \times 100$$

If apparent specific gravity is desired, it is determined by dividing the solid volume into the dry weight, w, of the test piece.

Advantages This apparatus is rugged and simple in its construction. It gives quite accurate values for all classes of ceramic bodies other than vitreous, on test pieces of wide variation from the general size 1 x 1 x 4 inches. Where many tests are being made, the mercury soon becomes dirty unless exceptional care is used to clean the test pieces before using. This apparatus is relatively insensitive to the small amount of dirt which gradually accumulates in any apparatus of this general type. Although this apparatus does not have the advantage of the direct reading feature, it is quite rapid and convenient in its operation.

Accuracy The accuracy attainable with this apparatus is all that can be necessary except for ware of the lowest porosities. For great accuracy, it is essential that the rubber tube does not stretch.

This is assured by having it enclosed in a snugly fitting flexible metal tube.

Indirect Reading Brick Porosimeter

Although Washburn and Bunting first described the general procedure and type of apparatus used in determining porosity values on commercial size brick by the air expansion method, it remained for Bole and Jackson[1] to modify and develop this method into a convenient and accurate means of determining porosities on standard size brick. In order to overcome the disadvantages of the inclined gage and glass containers used by Bole and Jackson, Pressler[2] developed an all-metal apparatus which made use of a simple vertical manometer. A slight modification of this apparatus has been in use in the Bureau of Mines laboratories for the past four years with quite satisfactory results. In each of these methods, solid volume is calculated from the pressure difference obtained after a definite expansion had taken place. Owing to the small bore manometer tubing used, a troublesome amount of tapping is required in order to assure that the mercury has come to equilibrium. Each of these methods called for the use of a motor driven vacuum pump as did that described by Hartmann, Westmont, and Morgan.[3] This of course adds greatly to the first cost of the apparatus as well as the inconvenience and expense of its operation. A water pump could be substituted with doubtful satisfactoriness. Although Pressler, and Bole and Jackson determined the bulk volume of the brick by direct measurement, Hartmann, Westmont, and Morgan introduced the method of bulk volume determination by sand displacement. This adds considerably to the precision of the values obtained on badly distorted brick. However, the method of direct measurement gives sufficiently accurate bulk volumes for all but the most irregularly shaped pieces.

In order to overcome the disadvantages in operation and expense of a vacuum pump and at the same time employ the advantages inherent in metallic containers, the apparatus shown in Fig. 3 was designed to operate on the general principle of gas expansion without employing a pump.

Apparatus The sample container is made of $\frac{1}{4}$-inch rolled steel plate with inside dimensions slightly larger than the standard

[1] G. A. Bole and F. G. Jackson, "A Simple Control Porosimeter," *Brick and Clay Rec.*, **61** [5], 314 (1922).

[2] E. E. Pressler, "A Simple Brick Porosimeter," *Jour. Amer. Ceram. Soc.*, **7**, 154 (1924).

[3] M. L. Hartmann, O. B. Westmont, and S. F. Morgan, "The Determination of the Bulk and Pore Volumes of Refractory Materials," *Jour. Amer. Ceram. Soc.*, **9** [5], 298–310 (1926).

dimensions of refractory brick. A cover plate made of steel plate is clamped in place by means of eight wing nut bolts and made air tight by a soft rubber gasket. However, the sample container covers could be ground to fit and made air tight by means of heavy stop-cock grease. Although a glass leveling bulb is used on the apparatus herein pictured, a metal leveling bulb could be used quite advantageously. The expansion bulb, manometer, and connections are made of glass. As these are fixed permanently and in no danger of being broken, glass is at no disadvantage. An ordinary heavy-walled rubber tube is used to connect the leveling bulb to the manometer.

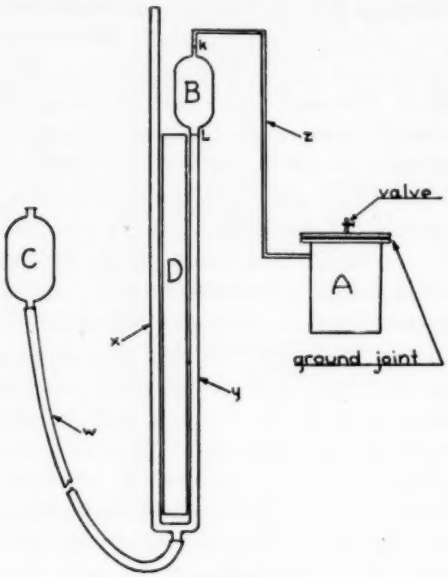

FIG. 3.

Figure 3 is a diagrammatic sketch of this apparatus. *A* is the brick container of about 2000 cc volume. The expansion bulb *B*, is made of glass and has a capacity of about 250 cc. *C* is a leveling bulb. *D* is an ordinary meter stick. The manometer, *x* and *y*, is made of glass tubing of about 5 millimeters internal diameter. Ordinary heavy-walled rubber tubing, *w*, is used and is not reinforced by a metallic covering as explained in the case of the other apparatus. *A* is connected to *B* by means of the capillary glass tube, *z*.

Operation Sufficient mercury having been previously placed in the leveling bulb to fill *B* up to the mark, *K*, the brick is placed in the sample container, *A*, and the cover put in place.

(1) *C* is elevated until the mercury level in *B* stands at *K* after which the stop-cock is closed.

(2) *C* is now lowered until the mercury level stands at *L*.

(3) The pressure difference in *x* and *y* is read on *D*. From this pressure difference the solid volume of the brick is calculated.

Calculation of Solid Volume (1) The reading, *R*, of *D* (as determined under 3 above) is subtracted from the barometric pressure in order to obtain the pressure, *p*, after the expansion process described under 1 and 2 above.

$$\text{(2) Air space } a, \text{ in } A = \frac{p \times B}{R}$$

B is the volume from *K* to *L*

(3) Solid volume, s, of test piece $= A - a$
A is the volume of the sample container

(4) Porosity in per cent $= \frac{v-s}{v} \times 100$

The bulk volume, v, of the brick is determined by direct measurement with a meter stick, the average of several readings in each dimension being taken.

If apparent specific gravity is desired, it is determined by dividing the solid volume into the dry weight, w, of the brick.

Accuracy The accuracy attainable with this apparatus and method is well within the limits ordinarily required in routine factory control, research and development work. In order to compare the values obtained by this apparatus with those obtained by the apparatus described by Pressler,[1] a series of determinations were run on the same test pieces using both apparatuses. Table II shows the data obtained. For a comparison of the porosity of different types of brick as determined by the liquid absorption and the air expansion methods, see the article by Hartmann, Westmont, and Morgan[1] and the one by Pressler.[2]

TABLE II

POROSITY OF BRICK

Pressler Method	MacGee Method
43.2	42.6
37.0	37.6
34.8	35.6
28.3	28.3
15.3	15.3

Advantages This apparatus combines the advantages of the accuracy of the air-expansion method with the cheapness of the liquid absorption method. There is no operating expense, such as is inherent in the type of apparatus employing a vacuum pump, either motor driven or employing water. The leveling bulb as well as the sample container is made of metal and the apparatus is therefore of quite rugged construction. The first cost is reduced to the absolute minimum and there is no dependence upon a source of electricity or water. (Owing to the large bore of the manometer tubing, tapping is not necessary.) Working very leisurely, the porosity and apparent specific gravity of a brick can be known within fifteen minutes from the time the test is begun.

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[1] *Loc. cit.*

[2] E. E. Pressler, "Comparative Tests of Porosity and Specific Gravity on Different Types of Refractory Brick," *Jour. Amer. Ceram. Soc.*, 7 [6], 447–51 (1924).

General

It is not essential that mercury be used as the suction medium in the brick porosimeter. This is because the liquid does not come into contact with the brick. Benzyl benzoate could quite advantageously be used if proper correction is made in the pressure difference reading for the difference in its specific gravity and that of mercury. This would lower the cost of the apparatus still more and would overcome the objection to mercury on account of its weight.

Although a knowledge of the barometric pressure is essential for the calculations, a barometer is not required because the barometric pressure can be determined with either of the three pieces of apparatus. This is determined by measuring the difference in pressure obtained when the air in the empty sample container is expanded a definite amount, namely, that of the expansion chamber. The barometric pressure is calculated as follows:

$P \times V = (P - d) \times v$ in which
P = barometric pressure
d = pressure difference after V is expanded to v
V = volume of sample container
$v = V +$ volume of expansion chamber

A number of containers in various sizes and shapes could be connected by means of capillary tubing to the one expansion chamber, thus having containers designed to accommodate brick, tile, grinding wheels, etc. This is desirable where various shapes are to be tested because maximum precision is attained when the free air space around the test piece is reduced to a minimum.

The author is grateful to E. E. Pressler of the Bureau of Standards for suggesting the logical extended application of the porosimeter in the determination of true specific gravity. This can be determined on dry powdered material by enclosing it in a porous cup and determining the solid volume of the cup alone and when filled with the powder.

Conclusions

1. A direct reading porosimeter based upon the principle of gas expansion is described. This reduces the calculations required to a minimum.

2. A convenient indirect reading porosimeter which gives very accurate values for porosity and apparent specific gravity on a wide range in size and shape of test pieces is described.

3. A ruggedly constructed brick porosimeter based upon the gas expansion principle is described. This apparatus reduces the cost of this type of porosimeter below that of any thus far developed.

BUREAU OF MINES
COLUMBUS, OHIO

ON THE DETERMINATION OF THE CONSTITUTION OF GLASSES[1]

By Kozo Tarata[2]

ABSTRACT

This method of determination of the constituents of glasses is entirely new in its way. It is derived from the author's experiments on the causes of the surface devitrification of glasses.

It is quite natural to produce crystals in glasses when heated several times at high temperatures. The glasses are supercooled liquids and are very viscous at low temperatures. But, when they are heated at higher temperatures, they attain low viscosities to produce crystals in them. In general, the chemical composition of the crystals produced (primary phase) in ordinary glasses without B_2O_3 is SiO_2. And for production of an elementary body of crystals of silica, there should be at least three neighboring molecules of silica moving within some ranges of speed. The motion of such molecules in glasses is set by two causes: the one is that quantity of energy given to the molecules by heating, and the other is that lowering of viscosity of the medium by heating. Heating glasses to certain temperatures is the exclusive cause of the crystal production of glasses.

This has been already explained by many persons and no ambiguity has been left unsolved.

The author has given another important cause for crystal production on glass surfaces and has described the interpretation.[3]

From these views, the author has arbitrarily defined devitrification in five degrees. They are seen in accompanying photographs. It has been determined that these degrees of devitrification were entirely coincident with the quantities of dissolved silica in glasses.

The experiments have been conducted for a series of glasses of alkali silicates and alkali lead silicates.

From the results of these experiments, the author has determined the constitutions of those silicates in glasses to be meta-disilicates and the double compounds to consist of those meta-disilicates.

As the result of the determination of the constituents of alkali silicates and of alkali lead silicate glasses, it is pointed out that the compositions of crucibles to melt glasses of different silica content, should be either rich Al_2O_3 or rich SiO_2 according to the dissolving power of glasses for silica.

Introductory

In the second report on the same subject,[3] the author has described some results on the devitrification of alkali lead silicates, giving his

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[3] Researches of the Electrotechnical Laboratory, No. 165, April, 1926. Tokyo, Japan.

view on the remarkable influence exerted by the presence of potassium oxide on the modes of devitrification of those glassy masses. We see also, in the photographs of the second report, that the modes of devitrification differ considerably between the cicatrized or sharp-edged portions and the flat or less sharp-edged portions. In other words, we see that the more the parts undergo surface contraction during the heat treatments the more the crystals are produced at those parts. And also the more the surfaces of the masses undergo surface contraction as a whole, the more the crystals are produced all over the surface; that is, as the differences of surface conditions both before and after the heat treatments are greater, so a greater number of crystals are produced.

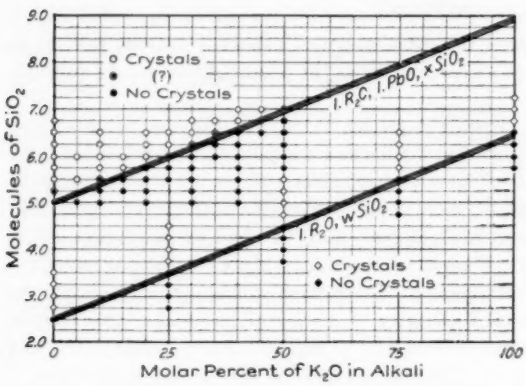

FIG. 1.—Experiments on the devitrification of alkali silicates and alkali lead silicates.

Taking account of the differences in the modes of devitrification as influenced by the surface conditions of the test samples, the author made experiments on the remarkable influence of the presence of K_2O in alkali lead silicates and in alkali silicates on the modes of devitrification after appropriate heat treatments.

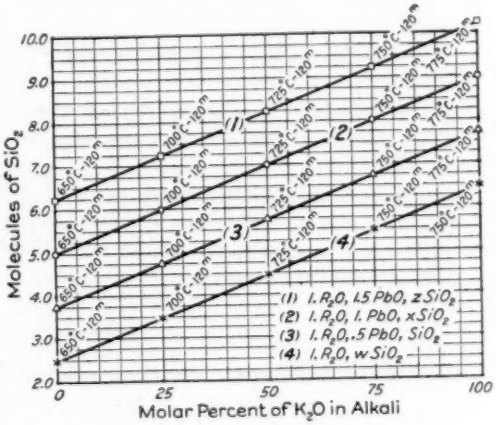

FIG. 2.—Heating conditions of devitrification along assumed lines of devitrification.

The samples used in the experiments were taken from their respective melts. Each component of the batches was dried and kept in a glass vessel avoiding moisture absorptions, etc. They were accurately weighed with a chemical balance. The chemical analysis of each material resulted as follows:

Results of Chemical Analysis

1. Sodium carbonate 99.99%
2. Potassium carbonate 99.99%
3. Silica

	Per cent		Per cent
SiO_2	96.96	CaO	0.18
Fe_2O_3	0.074	TiO_2	0.044
Al_2O_3	2.75	MnO	0.0012
		Total	100.01

4 and 5.

		Red Lead	Litharge
Impurities	Bi_2O_3	0.00087%	0.0005%
	MnO	0.0002%	0.0002%
	ZnO	0.011	0.027
	Fe_2O_3	0.029	0.019
	Al_2O_3	0.031	0.008
	TiO_2	0.001	0.0001
	SiO_2	0.066	0.015
	Moisture	—	0.030
	Pb_3O_4 (calculated)	100.20	—
	PbO (calculated)	—	99.97

The SiO_2 powder was used as 97% purity.

The crucibles were made of 70 parts of aluminous fireclay grog and 30 parts of bond clay. Their chemical composition was about 60% Al_2O_3 and 40% SiO_2.

The melting was conducted in a gas furnace. The time of heating and melting was 8 to 12 hours. The highest temperatures were between 1400 and 1550°C. The weight of batches was about 200 grams in each case.

The well-melted glasses were air quenched, the crucibles being taken from the furnace while bright red. The dark red color of the melts disappeared in about 15 to 20 minutes.

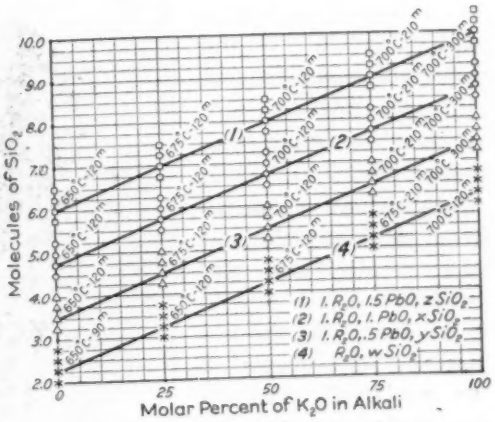

FIG. 3.—After-heating conditions for glasses along boundary lines.

Samples were taken generally from the central parts of the melts, and in some cases from the parts near to the walls of the crucibles. The experiments were conducted as follows.

In Part I, the relations between the quantities of K_2O and SiO_2 contained in series of alkali silicates composed of xNa_2O, yK_2O, $zSiO_2$, where $x+y=1$ and $z=2.5$ to 7 and the modes of devitrification upon appropriate heat treatments are described.

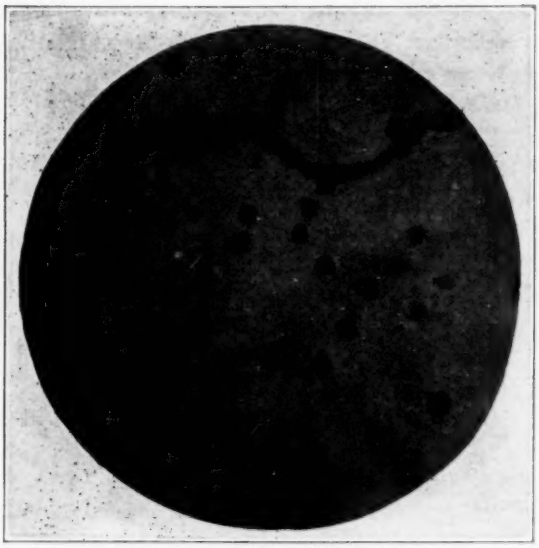

FIG. 4.—× 1000. 600°C–60m.

Those alkali silicates whose z are below 2.5 have been set outside of this experiment. They are not in direct relation to flint glasses. Their very instability in the atmosphere and probable difference of crystal forms in the primary phases from those of z of above 2.5 caused the author to make a special study of them as a separate problem.

In Part II, the effects of relative quantities of K_2O and SiO_2 on the modes of devitrification of alkali-lead-silicate melts whose batch composition is 1 R_2O, 1 PbO, $xSiO_2$, where x ranges from 4.75 to 9.5, and the results are described.

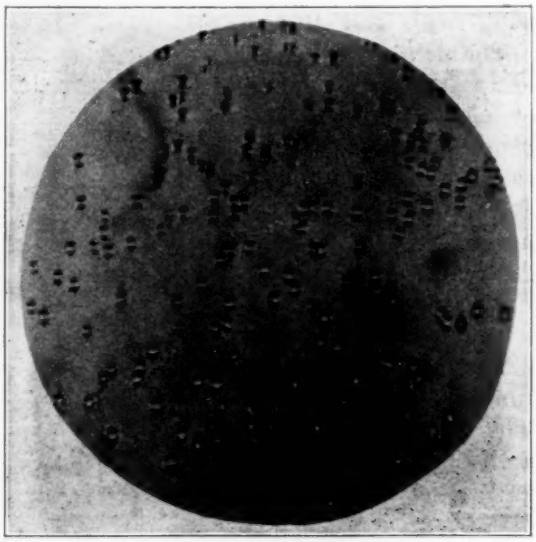

FIG. 5.—× 400. 600°C–120m.

In Part III, the degrees of devitrification as arbitrarily defined by the author are described, and the relation between the silica content and the degrees of devitrification are drawn in Figs. 19 and 20. Some photographs are attached to show the degrees of devitrification, the effects of different heat treatments on

crystal forms, and also the linear speed of crystal growths of β-quartz.

In Part IV, the experiments which have been conducted on glasses which are situated along assumed boundary lines of devitrification for each series of 1 R_2O, 1 PbO, $x SiO_2$; 2 R_2O, 1 PbO, $y SiO_2$; and 1 R_2O, 1.5 PbO, $z SiO_2$ glasses are described. In these experiments all the samples were previously heated above 950°C, air quenched, and cicatrized before heating for devitrifying. In other words, these experiments have been conducted under conditions of the severer devitrification.

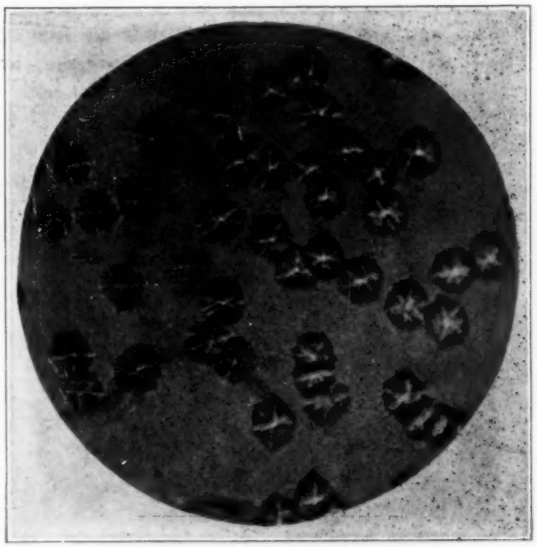

FIG. 6.—× 400. 600°C–240m.

In Part V,[1] the corresponding experiments on glasses of 1 R_2O, 0.5 CaO, $x SiO_2$ and 1 R_2O, 1 CaO, $y SiO_2$ are described.

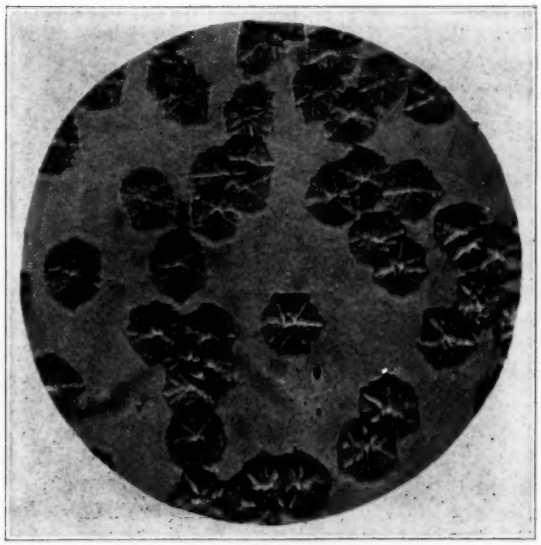

FIG. 7.—× 400. 600°C–300m.

In Part VI,[1] conclusions are given of alkali silicates, of alkali-lead silicates, and of the suitable compositions for the crucibles.

The experiments have been done in Dai-Gobu of the Electrotechnical Laboratory, Ministry of Communications, Japan. The author would express his sincere thanks to Y. Ogawa, chief of Dai-Gobu for his thoughtful advice, and to Sukezug Kimura for his kind advice in the consideration of the results of the experiments.

[1] Parts V and VI will appear in a paper by K. Tabata, "On the Causes of Surface Devitrification of Glasses," in *Jour. Amer. Ceram. Soc.*, January, 1927.

The author gives thanks also to his co-workers K. Yegami, S. Moriyasu, Y. Toda, Z. Ishibashi, C. Oginosho, C. Ogiso for their assistance in the completion of the experiments.

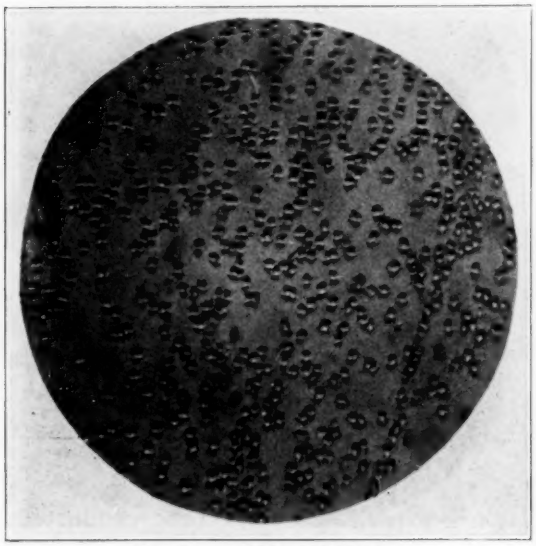

FIG. 8.—× 400. 675°C–30m.

Part I. Experiments on the Devitrification of Alkali Silicates

General Procedures Each sample of alkali silicate taken from broken pieces of air-quenched melts was cleansed and cicatrized.

Heating was conducted in an electric-muffle furnace as described in the second report.[1] Heat-treated samples were taken out from the furnace after predetermined times of heating, and air quenched.

They were pasted on glass plates and were observed through the microscope with magnifications from 90 to 1000.

Experiments Chemical compositions of the samples, heating conditions, surface conditions of the samples before and after the experiment, are tabulated in the Tables I to XIV.

The results gained by the microscopic observations are briefly written in degrees of devitrification, the explanation of which is to be seen in Part III.

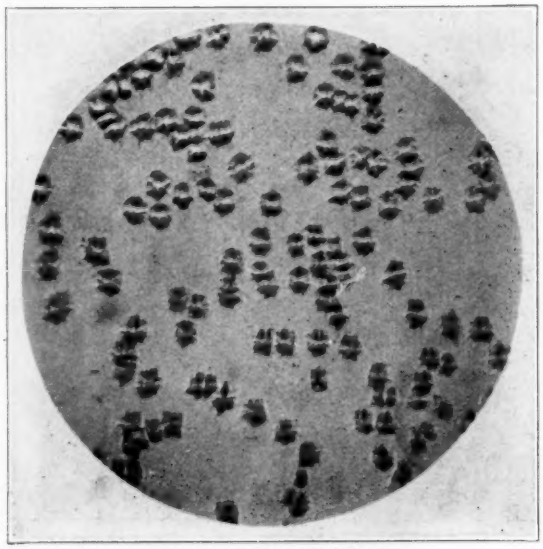

FIG. 9.—× 400. 675°C–60m.

[1] Researches of the Electrotechnical Laboratory, No. 165.

TABLE I

Experiments on 1.0 $K_2O-xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
113	23	3	725°C–120m	Broken piece	Rounded	
149	23	3	" "	Broken piece cicatrized	"	0
112	14	4	" "	Broken piece	"	
150	14	4	" "	Broken piece cicatrized	"	0
110	17	5	750°C–120m	Broken piece	"	
151	17	5	" "	Broken piece cicatrized	"	0
111	20	6	" "	Broken piece	Nearly	
130	20	6	" "	Broken piece cicatrized	rounded "	0
105	50	6.5	" "	Broken piece	"	
132	50	6.5	" "	Broken piece cicatrized	"	0(?)
157	51	6.75	750 C–150m	" "	"	1
159	52	7.0	" "	" "	"	2
161	53	7.25	" "	" "	"	3

TABLE II

Experiments on 0.75 K_2O, 0.25 Na_2O–$xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
115	28	3	700°C–120m	Broken piece	Rounded	
145	28	3	" "	Broken piece cicatrized	"	0
100	29	3.5	" "	Broken piece	"	
146	29	3.5	" "	Broken piece cicatrized	"	0
68	30	4	" "	Broken piece	"	
147	30	4	" "	Broken piece cicatrized	"	0
155	40	4.5	725°C–120m	Broken piece	"	
148	40	4.5	" "	Broken piece cicatrized	"	0
84	39	5	" "	Broken piece	"	
127	39	5	" "	Broken piece cicatrized	"	0
78	38	5.5	" "	Broken piece	"	
140	38	5.5	" "	Broken piece cicatrized	"	0(?)
109	37	6	750°C–120m	Broken piece	"	
129	37	6	" "	Broken piece cicatrized	"	1

TABLE II (*concluded*)

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
108	36	6.5	" "	Broken piece	"	
131	36	6.5	" "	Broken piece cicatrized	"	2
171	63	5.25	725°C–120m	" "	"	0
172	64	4.75	" "	" "	"	0
173	65	5.75	" "	" "	"	0(?)

TABLE III

Experiments on 0.5 K_2O, 0.5 Na_2O–$xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
51	24	3	675°C–120m	Broken piece	Rounded	
143	24	3	" "	Broken piece cicatrized	"	0
107	48	3.5	700°C–120m	Broken piece	"	
144	48	3.5	" "	Broken piece cicatrized	"	0
28	15	4	" "	Broken piece	"	
123	15	4	" "	Broken piece cicatrized	"	0
99	47	4.5	" "	Broken piece	"	
138	47	4.5	" "	Broken piece cicatrized	" "	0
40	18	5	725°C–120m	Broken piece	"	
126	18	5	" "	Broken piece cicatrized	"	1
118	49	5.5	" "	Broken piece	"	3
41	21	6	" "	" "	Nearly rounded	4
168	60	4.25	700°C–120m	Broken piece cicatrized	Rounded	0
169	61	4.75	" "	" "	"	0(?)
170	62	5.25	" "	" "	"	2

TABLE IV

Experiments on 0.25K_2O, 0.75Na_2O–$xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
95	46	3	675°C–120m	Broken piece	Rounded	
156	46	3	" "	Broken piece cicatrized	"	0
92	43	3.5	" "	Broken piece	"	
136	43	3.5	" "	Broken piece cicatrized	"	0(?)
87	42	4	700°C–120m	Broken piece	"	
122	42	4	" "	Broken piece cicatrized	"	1–2

TABLE IV (*concluded*)

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
83	41	4.5	" "	Broken piece	"	
124	41	4.5	" "	Broken piece cicatrized	"	2
76	31	5	725°C–120m	Broken piece	"	2–3
77	32	5.5	" "	" "	"	3
74	33	6	" "	" "	Rounded cracks	3–4
75	34	6.5	" "	" "	Nearly rounded cracks	4
165	57	2.75	650°C–120m	Broken piece cicatrized	Rounded white film	0
166	58	3.25	675°C–120m	" "	Rounded	0
167	59	3.75	" "	" "	"	1

TABLE V

Experiments on $1.0Na_2O$–$xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
119	45	3	675°C–120m	Broken piece	Rounded	
154	45	3	" "	Broken piece cicatrized	"	1–2
91	44	3.5	" "	Broken piece	"	
153	44	3.5	" "	Broken piece cicatrized	"	2
14	13	4	700°C–120m	Broken piece	"	2–3
22	16	5	725°C–120m	" "	Rounded cracks	3
34	19	6	" "	" "	Nearly rounded cracks	4
162	54	2.75	650°C–120m	Broken piece cicatrized	Rounded white film	1
163	55	2.50	" "	" "	"	0(?)
164	56	2.25	625°C–120m	" "	Thick white film	0(?)

Some Remarks on the Experiments

It is a matter for consideration that the differences of endurance for weathering of the alkali silicates should account for the modes of treatment during experiments.

Those below Na_2O, $2SiO_2$ and K_2O, $2.5SiO_2$ should be very quickly and carefully heat treated. $Na_2O,3SiO_2$ may be safely stored in a

closed glass vessel for several months without being weathered, but on the contrary K_2O, $3SiO_2$ cannot be stored. Even K_2O, $4SiO_2$ will be weathered if left standing for several (ten) days in glass-stoppered vessels.

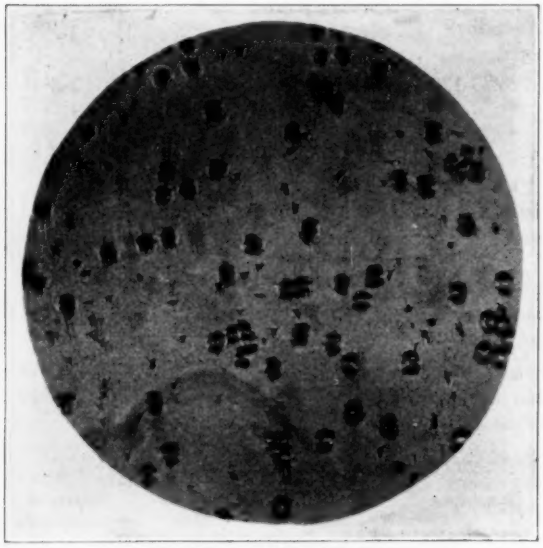

FIG. 10.—× 400. 700°C–30m.

The author observed that during the storage of K_2O, $2SiO_2$ and Na_2O, $2SiO_2$ at ordinary temperatures, there was no crystal production of quartz under microscopic observation up to 1000 times magnification. Yet in some cases, platy crystals appeared which might be sodium metadisilicate, while standing for several days after heat treatment.

The boundary line runs on the compositions of R_2O, $2SiO_2$ plus 0.5 mols of SiO_2 for Na_2O and plus 4.5 mols of SiO_2 for K_2O, and between both end points the line elevates according to the quantities of K_2O substituted for Na_2O, and makes a straight line.

The experiments were not conducted at the sharpest conditions, so that the author gave some allowance to the widths of the line, as seen in Fig. 1.

The compounds R_2O, $2SiO_2$ seem to be more stable, which will be seen from the results after heat treatment at varying temperatures and time duration.

The author thinks the formation of R_2O, $2SiO_2$ by melting SiO_2 $+R_2O.CO_2$ is sure to combine to form alkali silicates.

Part II. Experiments on the Devitrification of Alkali Lead Silicates

General Procedure The experiments have been conducted for a series of glasses whose molar composition is $1R_2O$, 1PbO, $xSiO_2$. Samples were taken from broken pieces of the melts which were very quickly cooled from the fluid state. Two samples of each melt, the one as it was and the other cicatrized, were put into the middle part of the electric-muffle furnace nearest to the

thermocouple junction at the same time, and heated at a predetermined temperature and time duration. After the heat treatment, the samples were taken out from the furnace and air quenched. They were pasted on a separate glass plate and were observed under the microscope with magnifications of 100' 250, and 1,000.

They were classified by the degree of devitrification as defined by the author (see Part III).

The results were plotted as shown in Fig. 1.

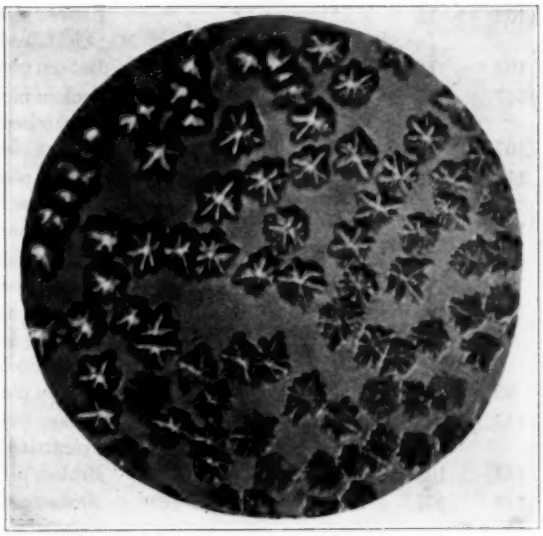

FIG. 11.—×400. 700°C–60m.

Other experiments supplementary to the above have been conducted. In this case, the samples were heated previously. They flowed to a somewhat flat surface. These were air quenched and cicatrized with sharp edges of rock crystal and then again heated under conditions as described in the table.

TABLE VI

Experiments on $1K_2O$, $1PbO$–$xSiO_2$

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	Surface condition After	Degree of devitrification
110	83	6.0	700°C–120m	Broken piece cicatrized	Rounded	0
110	83	6.0	" "	Broken piece	"	
105	78	6.5	" "	Broken piece cicatrized	"	0
105	78	6.5	" "	Broken piece	"	
118	92	5.5	650°C–120m	Broken piece cicatrized	"	0
118	92	5.5	" "	Broken piece	"	

TABLE VII

Experiments on $0.1K_2O$, $0.9Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	Surface condition After	Degree of devitrification
94	69	5.0	650°C–120m	Broken piece cicatrized	Rounded	0
94	69	"	" "	Broken piece	"	

TABLE VII (*concluded*)

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
102	75	"	" "	Broken piece cicatrized	"	0
102	75	"	" "	Broken piece	"	
107	75	"	" "	Broken piece cicatrized	"	0
107	75	"	" "	Broken piece	"	
113	86	"	" "	Broken piece cicatrized	"	0
113	86	"	" "	Broken piece	"	
125	95	5.5	675°C–120m	Broken piece cicatrized	"	0(?)
125	95	"	" "	Broken piece	"	
98	71	6.0	700°C–120m	Broken piece cicatrized	"	2
98	71	"	" "	Broken piece	"	
132	105	5.25	650°C–120m	Broken piece cicatrized	"	0
132	105	"	" "	Broken piece	"	
139	107	5.75	675°C–120m	Broken piece cicatrized	"	1
139	107	"	" "	Broken piece	"	
140	107	"	" "	Broken piece cicatrized	"	1
140	107	"	" "	Broken piece	"	
142	101	6.5	700°C–120m	Broken piece cicatrized	"	4
142	101	"	" "	Broken piece	"	
147	126	5.75	675°C–120m	Broken piece cicatrized	"	1
147	126	"	" "	Broken piece	"	
189	152	5.0	650°C–120m	Broken piece cicatrized	"	0
189	152	"	" "	Broken piece	"	

TABLE VIII

Experiments on $0.2K_2O$, $0.8Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
101	74	5.0	650°C–120m	Broken piece cicatrized	Rounded	0
101	74	5.0	" "	Broken piece	"	
133	106	5.25	" "	Broken piece cicatrized	"	0
133	106	5.25	" "	Broken piece	"	
120	81	6.0	700°C–120m	Broken piece cicatrized	"	0(?)
120	81	6.0	" "	Broken piece	"	

TABLE VIII (*concluded*)

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
121	88	6.0	" "	Broken piece cicatrized	"	0(?)
121	88	6.0	" "	Broken piece	"	
135	108	5.75	675°C–120^m	Broken piece cicatrized	"	0
135	108	5.75	" "	Broken piece	"	
137	110	6.25	700°C–120^m	Broken piece cicatrized	"	1
137	110	6.25	" "	Broken piece	"	
143	102	6.5	710°C–120^m	Broken piece cicatrized	"	3
143	102	6.5	" "	Broken piece	"	
145	98	5.5	675°C–120^m	Broken piece cicatrized	"	0
145	98	5.5	" "	Broken piece	"	
165	128	6.25	700°C–120^m	Broken piece cicatrized	Not rounded	0–1
165	128	6.25	" "	Broken piece	"	

TABLE IX

Experiments on $0.3K_2O$, $0.7Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
96	70	5.0	650°C–120^m	Broken piece cicatrized	Rounded	0
"	"	"	" "	Broken piece	"	
95	"	"	" "	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
126	96	5.5	675°C–120^m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
99	72	6.0	700°C–120^m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
108	80	"	" "	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
122	89	"	" "	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
136	109	5.75	675°C–120^m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
138	111	6.25	700°C–120^m	Broken piece cicatrized	"	0(?)
"	"	"	" "	Broken piece	"	

TABLE IX (*concluded*)

Expt. no.	Melt no	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
144	103	6.5	710°C–120m	Broken piece cicatrized	"	1–2
"	"	"	" "	Broken piece	"	
166	129	6.25	700°C–150m	Broken piece cicatrized	"	0(?)
"	"	"	" "	Broken piece	"	
176	134	6.75	725°C–120m	Broken piece cicatrized	"	2
"	"	"	" "	Broken piece	"	
191	154	5.0	650°C–120m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	

TABLE X

Experiments on $0.4K_2O$, $0.6Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
119	79	6.0	700°C–120m	Broken piece cicatrized	Rounded	0
"	"	"	" "	Broken piece	"	
141	112	6.25	" "	Broken piece cicatrized	"	0(?)
"	"	"	" "	Broken piece	"	
149	99	5.5	675°C–120m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
172	130	6.25	700°C–120m	Broken piece cicatrized	"	0(?)
"	"	"	" "	Broken piece	"	
192	163	6.5	725°C–120m	Broken piece cicatrized	"	0–1(?)
193	164	6.75	" "	" "	Nearly rounded	1
194	165	7.0	" "	" "	"	2

TABLE XI

Experiments on $0.5K_2O$, $0.5Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
127	97	5.5	650°C–120m	Broken piece cicatrized	Rounded	0
"	"	"	" "	Broken piece	"	
111	84	6.0	700°C–120m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
104	78	6.5	710°C–120m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	

TABLE XI (*concluded*)

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
163	162	5.5	675°C–120m	Broken piece cicatrized	"	0
"	"	"	" "	Broken piece	"	
178	136	6.75	725°C–120m	Broken piece cicatrized	"	0(?)
"	"	"	" "	Broken piece	"	
195	166	7.0	" "	Broken piece cicatrized	Nearly rounded	0–1

TABLE XII

Experiments on $0.6K_2O$, $0.4Na_2O$–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
150	100	5.5	650°C–120m	Broken piece cicatrized	Rounded "	0
"	"	"	" "	Broken piece		

TABLE XIII

Supplementary Experiments on K–Na Lead Silicates

Expt. no.	No. of mols. SiO_2	Temp.-time	Previous heating	Degree of devitrification
	A. $0.05K_2O$, $0.95Na_2O$, 1PbO, $xSiO_2$			
a	5.0	675°C–120m	950°C–60m	0
b	5.5	"	"	1–2
c	6.0	"	"	4
	B. $0.15K_2O$, $0.85Na_2O$, 1PbO, $xSiO_2$			
a	5.25	675°C–120m	950°C–60m	0
b	5.5	"	"	0(?)
c	5.75	"	"	2
d	6.0	"	"	3
	C. $0.25K_2O$, $0.75Na_2O$, 1PbO, $xSiO_2$			
a	5.5	700°C–120m	1000°C–60m	0
b	5.75	"	"	0
c	6.0	"	"	1–0
d	6.25	"	"	2
e	6.5	"	"	3
	D. $0.35K_2O$, $0.65Na_2O$, 1PbO, $xSiO_2$			
a	6.0	725°C–120m	1050°C–60m	0
b	6.25	"	"	0(?)
c	6.5	"	"	0–1
d	6.75	"	"	2
	E. $0.45K_2O$, $0.55Na_2O$, 1PbO, $xSiO_2$			
a	6.5	725°C–120m	1050°C–60m	0
b	6.75	"	"	0–1
c	7.0	"	"	1–2
d	7.25	"	"	3

TABLE XIV

Experiments on the Na–Lead Silicates

Expt. no.	Melt no.	No. of mol. SiO_2	Temp.-time	Surface condition Before	After	Degree of devitrification
100	73	5.0	700°C–120m	Broken piece	Rounded	0(?)
"	"	"	" "	cicatrized Broken piece	"	
106	"	"	650°C–120m	Broken piece	"	0–1
"	"	"	" "	cicatrized Broken piece	"	
112	85	"	" "	Broken piece	"	0(?)
"	"	"	" "	cicatrized Broken piece	"	
109	82	6.0	700°C–120m	Broken piece	"	2–3
"	"	"	" "	cicatrized Broken piece	"	
103	76	6.5	710°C–60m	Broken piece	"	4
"	"	"	" "	cicatrized Broken piece	"	
117	91	5.5	675°C–120m	Broken piece	"	1
"	"	"	" "	cicatrized Broken piece	"	
131	104	5.25	650°C–120m	Broken piece	"	0(?)
"	"	"	" "	cicatrized Broken piece	"	
146	125	5.75	675°C–120m	Broken piece	"	1–2
"	"	"	" "	cicatrized Broken piece	"	
148	127	"	" "	Broken piece	"	1–2
"	"	"	" "	cicatrized Broken piece	"	
173	149	6.25	700°C–120m	Broken piece	"	3–4
"	"	"	" "	cicatrized Broken piece	"	
174	150	6.50	" "	Broken piece	"	4
"	"	"	" "	cicatrized Broken piece	"	
175	151	6.75	" "	Broken piece	"	4
"	"	"	" "	cicatrized Broken piece	"	

Summary of the Results of the Experiments

The results of the experiments are plotted in Fig. 1. Although the surface conditions were somewhat irregular and the samples were not good in a strict sense because the weighing and mixing of

batch compositions were not perfect and also because the melting conditions and the conditions for crucibles did not coincide in every case, the experiments had not been done for the series of 0.75 K_2O, 0.25 Na_2O, 1PbO, xSiO; nor for those $1K_2O$, 1PbO, $xSiO_2$ near the boundary line.

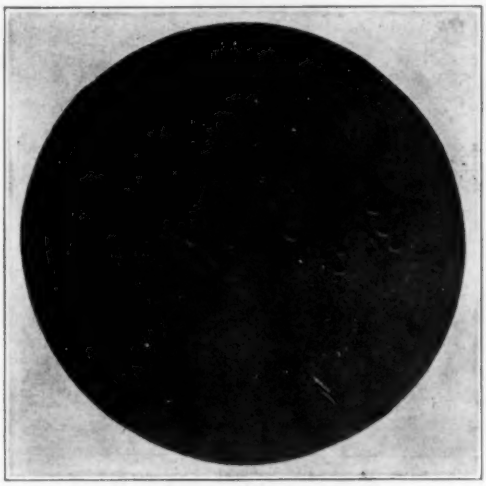

FIG. 12.—× 200. Degree 1.

It seemed to be somewhat hazardous to draw a boundary line of devitrification for the series of glasses of $1R_2O$, 1PbO, $xSiO_2$ from the results of one-half the length of the entire line. However, the results of each series of glasses parallel to the ordinate in Fig. 1, resulted in distinct degrees of devitrification above the zero degree.

It was necessary for the determination of the zero degree and one degree of any sample that skilful observations be made of definite surface conditions, appropriate heating conditions, etc.; yet for degree two, degree three, and degree four the conditions were not so strict. In other words the vigorous crystal production of those glasses overcame the minute differences in the conditions and rather regular devitrification on the surface had resulted. Degrees proceeded by one with the increase of 0.25 mols of silica for a series of glasses parallel to the ordinate.

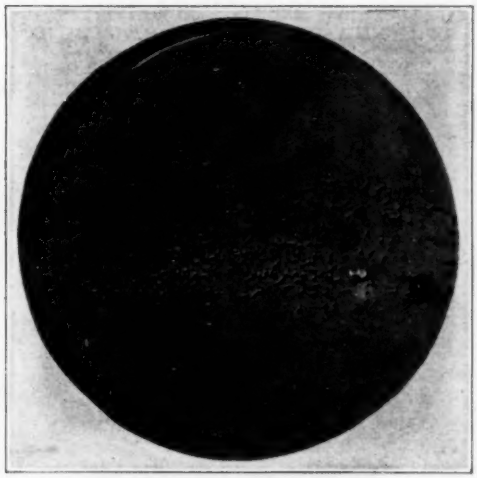

FIG. 13.—× 200. Degree 2.

The state of crystal production had been cautiously observed with considerations of different heating conditions. Observations on these points gave something to the author. The degrees moved sometimes by half under different heating temperatures.

Thus, the author drew an assumed boundary line of devitrification for the series of glasses, 1 R_2O, 1 PbO, $xSiO_2$.

The corresponding boundary lines of 1 R_2O, $wSiO_2$, and of 1 R_2O, 1 PbO, $xSiO_2$ ran parallel to each other.

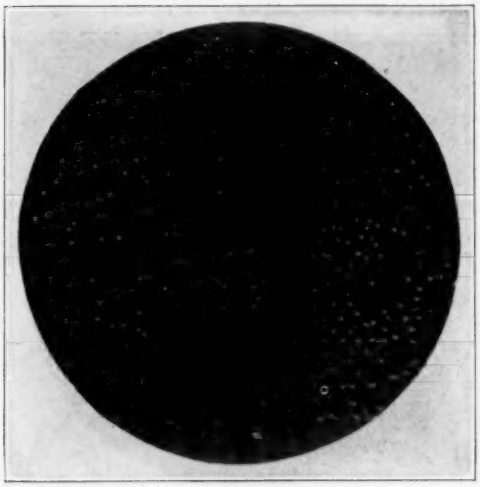

FIG. 14.—× 200. Degree 3.

Part III. Degrees of Devitrification

Classification of Degree of Devitrification

The author classified the degrees of devitrification as follows:

Degree 0, no crystals;

Degree 1, a few, minute crystals at specified places such as at sharpest edges of cicatrices.

Degree 2, many crystals along sharp edges or at cicatrized portion.

Degree 3, crystals on all the surfaces, namely, crystals produced on the glass surfaces without sharp edges or cicatrices.

Degree 4, crystals cover all over the surfaces or maximum production of crystals on the surfaces.

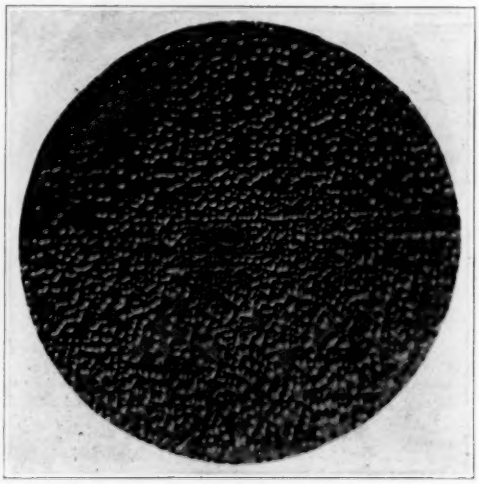

FIG. 15.—× 200. Degree 4.

This classification is very convenient in comparing the results of experiments on devitrification of similar kinds of glasses having different percentage compositions.

The basis of this classification depends on the author's view of the causes of surface devitrification of glasses.[1] The formation of crystal nuclei or crystal

[1] To appear in *Jour. Amer. Ceram. Soc.*, January, 1927.

centers is mainly effected by the heating temperatures. Owing to the greater viscosity of glasses containing high percentages of SiO_2 molecules, some glasses which are situated along or above boundary lines of devitrification, are difficult to soften in 120 minutes heating at temperatures below 700°C.

The author has assigned the minimum time of heating at 120 minutes and the temperature of heating is such that, after the heat treatments, the samples become round by surface contraction.

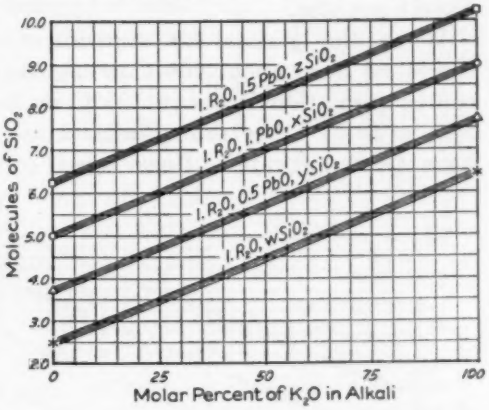

FIG. 16.—Assumed boundary lines of devitrification for alkali silicates and alkali lead silicates.

However, the most important thing in the manipulation is that the sharpest edges round up very slowly or only surface contraction takes place which is caused by surface tension acting to deform the sharp edges. In other words, the flow of glasses at sharp edges caused by other than surface contraction should be avoided, or any disturbance in crystal nucleus formation during heat treatments should be avoided. It is very desirable to use temperatures between 650–675° or 625–700°C for devitrification, as in these ranges of temperature, the crystals to be produced are definite (being β-quartz), and the linear rates of growth of β-quartz are greater than other types of crystals. Photographs show the rates of linear growth of β-quartz and those of tridymite (?). The samples were Marconi M. T. 4 glass, and no cicatrices. The experiments were conducted at an early period of the author's experiments when the surface conditions had not been so seriously considered. The magnifications were 400 times except one, that of 600°C−120^m.

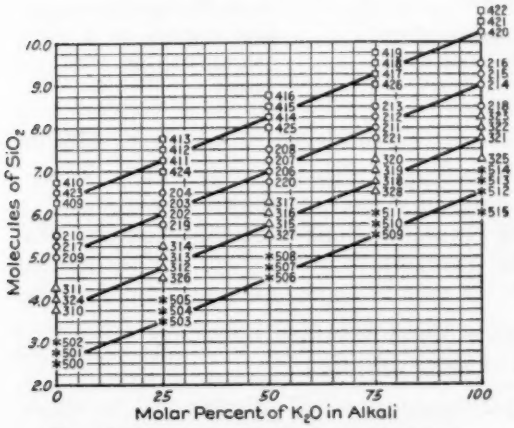

FIG. 17.—Melt numbers and experiment numbers along assumed lines of devitrification.

To observe the crystals produced, it is necessary that the crystals have some size.

When the glasses for experiment are previously heated and quenched from about 900°C or above, and the heating for crystal center formation is above 725°C or more, different modifications of SiO_2 crystals other than β-quartz are occasionally produced which have a different rate of linear speed of crystal growths.[1]

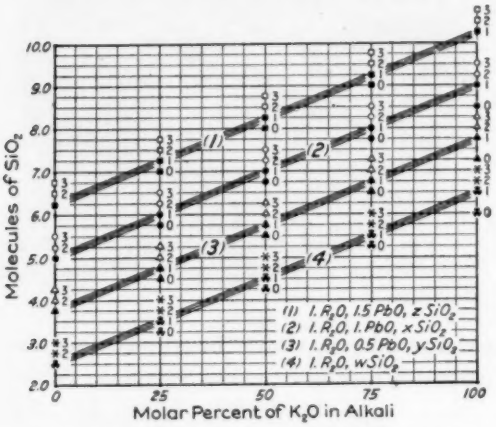

FIG. 18.—Degrees of devitrification along assumed lines of devitrification. (The numbers show degrees of devitrification.)

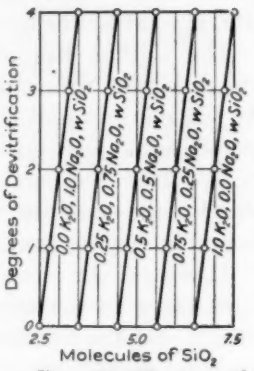
Degrees of Devitrification
Molecules of SiO2
0.0 K2O, 1.0 Na2O, wSiO2
0.25 K2O, 0.75 Na2O, wSiO2
0.5 K2O, 0.5 Na2O, wSiO2
0.75 K2O, 0.25 Na2O, wSiO2
1.0 K2O, 0.0 Na2O, wSiO2

FIG. 19.—Degrees of devitrification for alkali lead silicates, as determined by the experiments.

For clearer observation of such crystals or those very minute crystals which did not grow to sufficient size, the author gave "after-heating conditions" for each series of glasses, as shown in Fig. 3.

Under these conditions, the crystallizations were vigorous and the growths of crystals proceeded regularly.

Part IV. Experiments Along Assumed Boundary Lines of Devitrification

From the results of the experiments on alkali silicates and on alkali lead silicates which are given in the preceding pages, the author deduced assumed lines of devitrification for alkali lead silicates, $1R_2O$, 0.5 PbO, $ySiO_2$; $1R_2O$, 1.5 PbO, $zSiO_2$ running parallel to those lines of $1R_2O$, $wSiO_2$ and $1R_2O$, 1PbO, $xSiO_2$ as are shown in Fig. 16.

[1] The heating conditions are assigned as are seen in the Tables XV, XVI, XVII, and XVIII, for the respective series of glasses of alkali silicates and alkali lead silicates. When the compositions of glasses situated between those described, the heating conditions are set to the intermediate. And if the composition is near to some one of the assigned, the same heating conditions are given, etc.

Referring to the literature upon alkali silicates and on lead silicates, the author thought it reasonable to assume only the presence of di-compounds of alkali silicates and lead silicates in glasses having such compositions under the experiments and being melted at high temperatures and being air quenched from the fluid state.

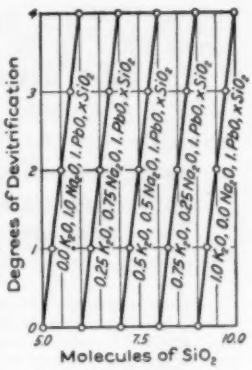

FIG. 20.—Degrees of devitrification for alkali lead silicates as determined by the experiments.

The predetermined boundary line of $1R_2O$, $1PbO$, $xSiO_2$ starts at 5 mols of silica and ends at 9 mols while that of $1R_2O$, $wSiO_2$ starts at 2.5 mols of silica and ends at 6.5 mols of silica in Fig. 1. In other words, one mol of Na_2O, $2SiO_2$ dissolves 0.5 mol of silica and one mol of K_2O, $2SiO_2$ 4.5 mols of silica. The number of mols of silica at the starting point should consist of 2.5 mols of silica for alkali silicate plus 2.5 mols of silica for lead silicate. So that 1 mol of $1PbO$, $2SiO_2$ dissolves 0.5 mols of silica without crystal production after heat treatment under the conditions of these experiments.

Thus, the author drew lines as assumed boundary lines of devitrification for $1R_2O$, 0.5 PbO, $ySiO_2$ and $1R_2O$, 1.5PbO, $zSiO_2$ running parallel to those predetermined boundary lines of devitrification of 1 R_2O, 1 PbO, $xSiO_2$ and 1 R_2O, $wSiO_2$. The distances along the ordinate between those lines have been fixed as 1.25 mols of silica for every 0.5 mols of PbO. These are shown in Fig. 16.

General Remarks of the Experiments

In the experiments, the crucibles, the melting procedures, the rapid cooling of the melts, the weighing of the batch compositions, and heating conditions, and observations by microscope etc., had been so controlled that the results gained had been observed with the least ambiguity. However, some disturbances had occurred to those near the zero degree of devitrification for glasses of $1Na_2O$, $1PbO$, $xSiO_2$. They might be due to the insufficient dryness in the heating furnace. In some instances, the author had observed the escaping of water vapor when the door of the furnace had been opened after heat treatment.

The crucibles used in these experiments had been manufactured by the co-workers of the author. To 70 to 80 parts of aluminous grog, 30 to 20 parts of aluminous bond clay were added, well mixed and formed by skilful hand, and carefully dried and ignited at about 1200°C. They were very resistant to sudden changes of temperature. They were safely heated with batch of about 200 grams in them to

about 1000°C or higher in a few minutes; and also could be cooled to some 500°C in the air with melts in the fluid state.

For batch mixtures, elutriated silica powder of 97% purity with 2.75% Al_2O_3 and a few impurities, and chemically pure anhydrous Na_2CO_3, K_2CO_3, PbO, and Pb_3O_4 were used.

Each was perfectly dried and preserved in separate glass vessels. Each was accurately weighed with a chemical balance.

They were well mixed in porcelain mortars and transferred into crucibles.

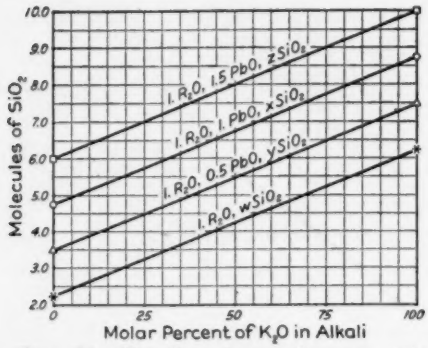

FIG. 21.—Results of experiments. The boundary lines.

Three crucibles had been heated at the same time in a gas furnace. The heating temperatures had been quickly raised to about 800°C and then slowly to about 1100°C. After the end of sintering of the entire mass, the temperatures had been quickly elevated again to about 1400 to 1550°C according to the silica content of the batch. The highest temperatures had been continued from two to six hours according to the silica content of the glasses melted.

The cooling of the melts was always done quickly. The fire of the furnace was put out, the door was opened, and the crucibles were taken up with the tongs into the atmosphere while they were at white heat. The color of the melts became dark red in several minutes.

The cooled melts were broken to pieces; the pieces from the central parts were used as the samples for the experiments of devitrification.

The samples were heated previously above 950 or 1000°C for about 60 minutes in an electric-muffle furnace. The curvatures of the flowed mass were somewhat different according to their chemical composition. Yet, it might generally be said that the surface conditions had been improved very much compared with those conditions as used in the experiments in Parts I and II. These flowed pieces of test samples were quenched in the air and cicatrized with sharp edges of rock crystals.

In devitrifying those samples, the heating was conducted under the conditions as assigned (see Part III) and the microscopic observations were the same as before.

In the course of the experiments, close attention was paid to the samples in their size, form, cicatrization, and other points which might affect the surface contraction. In the microscopic observations

not only the number, size, and form of crystals produced were carefully observed but also the changes of surface curvatures, and state of bubbles appearing during heating, etc., were cautiously taken into account for the degrees of devitrification.

The Experiments The chemical compositions (batch) of the sample glasses, the melt numbers, the experiment numbers, heating conditions, surface conditions, and degrees of devitrification are tabulated in Tables XV to XVIII. In the tables, heating conditions, *a* denotes heating for flowing samples to get unique curvature and *b* expresses conditions of heating for devitrification.

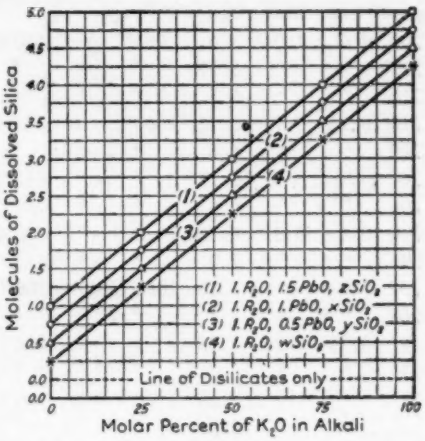
Molecules of Dissolved Silica
Molar Percent of K_2O in Alkali
(1) 1 R_2O, 1.5 PbO, z SiO_2
(2) 1 R_2O, 1 PbO, x SiO_2
(3) 1 R_2O, 0.5 PbO, y SiO_2
(4) 1 R_2O, w SiO_2
Line of Disilicates only

FIG. 22.—Saturation lines for alkali lead silicates and for alkali silicates.

TABLE XV

Experiments on $1R_2O$, $0.5PbO$, $ySiO_2$

Melt nos. / Expt. nos.	No. of mols. K_2O	Na_2O	SiO_2	Heating conditions *a*	Heating conditions *b*	Surface conditions Before	Surface conditions After	Degree of devitrification
310	0.0	1.0	3.75	950°C–60m	650°C–120m	Flat-round	Spheric-round	1
324	"	"	4.0	" "	" "	"	"	2
311	"	"	4.25	" "	" "	"	"	3
326	0.25	0.75	4.5	1000°C–60m	675°C–120m	"	"	0
312	"	"	4.75	" "	" "	"	"	1
313	"	"	5.0	" "	675°C–180m	"	"	2
314	"	"	5.25	" "	" "	"	"	3
327	0.5	0.5	5.5	" "	700°C–120m	"	"	0
315	"	"	5.75	" "	" "	"	"	1
316	"	"	6.0	1050°C–60m	700°C–150m	"	"	2
317	"	"	6.25	" "	" "	"	"	3
328	0.75	0.25	6.5	" "	700°C–210m	"	"	0
318	"	"	6.75	" "	" "	"	"	1
319	"	"	7.0	1100°C–60m	700°C–240m	"	"	2
320	"	"	7.25	" "	" "	"	"	3
321	1.0	0.0	7.75	" "	700°C–300m	"	"	1
322	"	"	8.0	" "	" "	"	"	2
323	"	"	8.25	" "	" "	"	"	3
325	"	"	7.25	" "	" "	"	"	0

TABLE XVI

Experiments on $1R_2O$, $1PbO$, $xSiO_2$

Melt nos. / Expt. nos.	No. of mols. K_2O	Na_2O	SiO_2	Heating conditions *a*	*b*	Surface conditions Before	After	Degree of devitrification
209	0.0	1.0	5.0	950°C–60m	650°C–120m	Flat-round	Spheric-round	1
217	"	"	5.25	" "	" "	"	"	2
210	"	"	5.5	" "	" "	"	"	3
219	0.25	0.75	5.75	1000°C–60m	675°C–120m	"	"	0
202	"	"	6.0	" "	" "	"	"	1
203	"	"	6.25	" "	675°C–180m	"	"	2
204	"	"	6.5	" "	" "	"	"	3
220	0.5	0.5	6.75	" "	700°C–120m	"	"	0
206	"	"	7.0	" "	" "	"	"	1
207	"	"	7.25	1050°C–60m	700°C–150m	"	"	2
208	"	"	7.5	" "	" "	"	"	3
221	0.75	0.25	7.75	" "	700°C–210m	"	"	0
211	"	"	8.0	" "	" "	"	"	1
212	"	"	8.25	1100°C–60m	700°C–240m	"	"	2
213	"	"	8.5	" "	" "	"	"	3
218	1.0	0.0	8.5	" "	700°C–300m	"	"	0
214	"	"	9.0	" "	" "	"	"	1
215	"	"	9.25	" "	" "	"	"	2
216	"	"	9.5	" "	" "	"	"	3

TABLE XVII

Experiments on $1R_2O$, $1.5PbO$, $zSiO_2$

Melt nos. / Expt. nos.	No. of mols. K_2O	Na_2O	SiO_2	Heating conditions *a*	*b*	Surface conditions Before	After	Degrees of devitrification
409	0.0	1.0	6.25	950°C–60m	650°C–120m	Flat-round	Spheric-round	1
423	"	"	6.5	" "	" "	"	"	2
410	"	"	6.75	" "	" "	"	"	3
424	0.25	0.75	7.0	1000°C–60m	675°C–120m	"	"	0
411	"	"	7.25	" "	" "	"	"	1
412	"	"	7.5	" "	675°C–180m	"	"	2
413	"	"	7.75	" "	" "	"	"	3
425	0.5	0.5	8.0	" "	700°C–120m	"	"	0
414	"	"	8.25	" "	" "	"	"	1
415	"	"	8.5	1050°C–60m	700°C–150m	"	"	2
416	"	"	8.75	" "	" "	"	"	3
426	0.75	0.25	9.0	" "	700°C–210m	"	"	0
417	"	"	9.25	" "	" "	"	"	1
418	"	"	9.5	1100°C–60m	700°C–240m	"	"	2
419	"	"	9.75	" "	" "	"	"	3
420	1.0	0.0	10.25	" "	700°C–300m	"	"	1
421	"	"	10.5	" "	" "	"	"	2
422	"	"	10.75	" "	" "	"	"	3

TABLE XVIII

Experiments on $1R_2O$, $wSiO_2$

Melt nos.	No. of mols.			Heating conditions				Surface conditions		Degrees of
Expt. nos.	K_2O	Na_2O	SiO_2	a		b		before	after	devitrification
500	0.0	1.0	2.5	950°C–60^m		650°C–120^m		Flat-round	Spheric-round	1
501	"	"	2.75	"	"	"	"	"	"	2
502	"	"	3.0	"	"	"	"	"	"	3
503	0.25	0.75	3.5	"	"	"	"	"	"	1
504	"	"	3.75	"	"	"	"	"	"	2
505	"	"	4.0	"	"	"	"	"	"	3
506	0.5	0.5	4.5	"	"	675°C–120^m		"	"	1
507	"	"	4.75	"	"	"	"	"	"	2
508	"	"	5.0	1000°C–60^m		"	"	"	"	3
509	0.75	0.25	5.5	"	"	"	"	"	"	1
510	"	"	5.75	"	"	"	"	"	"	2
511	"	"	6.0	"	"	700°C–120^m		"	"	3
515	1.0	0.0	6.0	"	"	"	"	"	"	0
512	"	"	6.5	"	"	"	"	"	"	1
513	"	"	6.75	"	"	"	"	"	"	2
514	"	"	7.0	"	"	"	"	"	"	3

During the observations, the author gave some consideration to the practical applications of this method of devitrification, and gave another heating condition for glasses along boundary lines of devitrification, as shown in Fig. 2. When the crystals are minute and the magnifying powers of the microscope are low, the observation may become somewhat troublesome. It is better to heat samples again under conditions shown in Fig. 3. By the reheating minute crystals will grow large enough to be easily observed. In Fig. 17 the experiment numbers, melt numbers, the compositions, and in Fig. 8 the degree of devitrification, respectively, are plotted for brevity.

Summary of the Results

From the results of the experiments, it is summarized that:

1. The solution of silica in alkali silicates is different according to the relative quantities of K_2O and Na_2O contained in them. One mol of $1Na_2O$, $2SiO_2$ dissolves up to about 0.25 mols of SiO_2 without producing crystals of β-quartz upon heating at 650°C–120 minutes, and $1K_2O$, $2SiO_2$ dissolves up to about 4.25 mols of SiO_2 with no production of SiO_2 crystals on heating at 725°C–120 minutes.

2. The quantities of silica dissolved in series of Na-K silicate glasses without crystal production on appropriate heat treatments increase by the substitution of Na by K, and the relation is entirely "additive."

3. The author names the line connecting the uppermost points of no crystal production, "boundary line of devitrification" for technical use or "saturation line" for scientific use.

4. This boundary line of alkali silicate is a straight line.

5. The line connecting points of no crystal production for each alkali

lead silicate of $1R_2O$, 0.5 PbO, $ySiO_2$; $1R_2O$, 1PbO, $xSiO_2$; and $1R_2O$, 1.5 PbO, $zSiO_2$ is also a straight line.

6. These four straight lines run parallel to each other.

7. The distances of these four lines along ordinates are equal. Starting at $1R_2O$, $wSiO_2$, the distance is 1.25 mols of silica to $1R_2O$, 0.5 PbO, $ySiO_2$, to $1R_2O$, 1PbO, $xSiO_2$ and to $1R_2O$, 1.5 PbO, $zSiO_2$ respectively as shown in Fig. 5.

8. The degree of devitrification is clearly distinguished. The degrees 0, 1, 2, 3, and 4 always follow by a difference of about 0.25 mols of SiO_2 in excess.

9. The crystals (in primary phase) produced are β-quartz under the conditions as applied at temperatures below 675°C. Some, below 650°C and under shorter time of heating, seemed to be α-quartz.

10. The crystals (in primary phase) produced above 725°C are of β-quartz and in some cases are of tridymite (?).

11. The crystals of β-quartz produced are always the top parts along c axis, no other planes appearing.

12. The Tables I and II are the calculated percentage compositions on degree 0 and degree 1 lines of devitrification.

13. The degrees of devitrification obtained by the experiments are plotted in Figure 18.

14. As the results of the experiments, the degree 0 lines of devitrification are drawn as shown in Fig. 9.

TABLE XIX

Chemical Compositions of Least Devitrifiable Glasses

Molar compositions on degree 1 lines	Melt nos.	Percentage compositions (calculated) K_2O	Na_2O	PbO	SiO_2	Total
	409	—	8.01	43.27	48.71	99.99
	411	2.80	5.52	39.77	51.92	100.01
R_2O, 1.5PbO, $zSiO_2$	414	5.17	3.41	36.78	54.65	100.01
	417	7.22	1.58	34.21	56.99	99.99
	420	8.99	—	31.98	59.05	100.02
	209	—	10.57	38.05	51.40	100.02
	202	3.60	7.10	34.07	55.23	100.00
$1R_2O$, 1.0PbO, $xSiO_2$	206	6.51	4.29	30.86	58.35	100.01
	211	8.93	1.96	28.19	60.89	99.97
	214	10.94	—	25.98	63.08	100.00
	310	—	15.52	29.93	56.53	99.98
	312	5.03	9.94	23.84	61.19	100.00
$1R_2O$, 0.5PbO, $ySiO_2$	315	8.78	5.78	20.80	64.65	100.01
	318	11.69	2.56	18.45	67.32	100.02
	321	14.00	—	16.58	69.42	100.00
	500	—	29.13	—	70.86	99.99
	503	8.38	16.54	—	75.08	100.00
$1R_2O$, $wSiO_2$	506	13.48	8.87	—	77.66	100.01
	509	16.91	3.71	—	79.38	100.00
	510	19.37	—	—	80.61	99.98

TABLE XX

Chemical Compositions of Glasses on Boundary Lines

	Molar compositions on degree 0 lines			Percentage compositions (calculated)				
				K_2O	Na_2O	PbO	SiO_2	Total
1 R_2O, 1.5 PbO, $zSiO_2$	1Na_2O,	1.5PbO,	6SiO_2	—	8.173	44.134	47.693	100.000
	0.25 K_2O / 0.75 Na_2O	"	7 "	2.848	5.623	40.486	51.043	"
	0.5 K_2O / 0.5 Na_2O	"	8 "	5.261	3.463	37.395	53.887	100.006
	0.75 K_2O / 0.25Na_2O	"	9 "	7.332	1.608	34.743	56.317	100.000
	1K_2O			9.128	—	32.442	58.430	"
1 R_2O 1.0 PbO, $xSiO_2$	1Na_2O,	1.0PbO,	4.75SiO_2	—	10.846	39.047	50.107	"
	0.25K_2O / 0.75Na_2O	"	4.75 "	3.680	7.266	34.876	54.178	"
	0.5K_2O / 0.5Na_2O	"	6.75 "	6.650	4.377	31.511	57.463	100.001
	0.75K_2O / 0.25Na_2O	"	7.75 "	9.096	1.966	28.738	60.170	100.000
	1K_2O		18.75 "	11.148	—	26.414	62.438	"
1 R_2O 0.5 PbO, $ySiO_2$	1Na_2O,	0.5PbO,	3.5SiO_2	—	16.118	29.014	54.868	"
	0.25K_2O / 0.75Na_2O	"	4.5 "	5.199	10.265	24.636	59.901	100.001
	0.5K_2O / 0.5Na_2O	"	5.5 "	9.034	5.946	21.406	63.614	100.000
	0.75K_2O / 0.25Na_2O	"	6.5 "	11.981	2.628	18.925	66.466	"
	1K_2O	"	7.5 "	14.315	—	16.959	68.726	"
1 R_2O, $wSiO_2$	1Na_2O,	2.25SiO_2		—	31.365	—	68.635	"
	0.25K_2O / 0.75Na_2O	3.25 "		8.853	17.480	—	73.668	"
	0.5K_2O / 0.5Na_2O	4.25 "		14.086	9.271	—	76.642	99.999
	0.75K_2O / 0.25Na_2O	5.25 "		17.543	3.849	—	78.608	100.000
	1K_2O	6.25 "		19.997	—	—	80.003	"

Conclusions

1. The constitutions of alkali silicates are xNa_2O, $2SiO_2+yK_2O$, $2SiO_2+zSiO_2$. The dissolving powers of Na_2O, $2SiO_2$ and K_2O, $2SiO_2$ for SiO_2 differ very much. The author assumes the cause of the different dissolving power to be attributed to the difference of the atomic structure of both atoms of Na and K.

2. The constitutions of ordinary flint glasses are $x(1R_2O, 2SiO_2, 1PbO, 2SiO_2)+y(1R_2O, 2SiO_2)+z(1PbO, 2SiO_2)+wSiO_2$.

3. For the compositions of crucibles for flint glass melting, the author gives the following standards:

(*a*) For glasses which contain excess silica or situated above saturation lines in Fig. 22: silica rich crucibles.

(*b*) For glasses which contain insufficient silica or situated below saturation lines in Fig. 22: alumina rich crucibles.

SOURCES OF ERROR IN GLASS VOLUMETRIC APPARATUS[1]

By H. V. E. M. Renn

ABSTRACT

The most serious source of error is the original calibrating operation. Errors introduced are due principally to following causes: (*a*) volumetric inaccuracy, (*b*) variation of bore, (*c*) delivery time, (*d*) incorrect marking of the meniscus, (*e*) after-working of the glass. Elimination of errors due to these causes is discussed. An apparatus for the calibration of volumetric apparatus is described. A source of error that is not usually recognized is the occurence of after-changes in the glass during a period immediately following manufacture. The length of this period varies with the composition of the glass. Experiments by the writer upon glass volumetric apparatus show that a period of seven months is usually sufficient in order to avoid excessive error from this source.

In the manufacture of glass volumetric apparatus every precaution has to be taken to avoid the introduction of error. What is regarded as the most serious source of error is the original calibrating operation, in which the required volume or some definite fraction of it, is marked off on the vessel.

Cause of Errors

Errors introduced are, in the main, due to the following causes:

(*a*) Volumetric inaccuracy
(*b*) Variation of bore
(*c*) Delivery time
(*d*) Incorrect marking of the meniscus
(*e*) After-working of the glass

(a) Volumetric Inaccuracy

The most accurate means of measuring a volume of liquid is, of course, by weighing, but this is long and tedious and is not by any means a commercial proposition. Various forms of apparatus have been proposed from time to time[2] which are intended to transfer a rapidly and accurately measured volume of liquid to the vessel being calibrated. The basis of most such apparatus is volumetric measurement, consisting in drawing off the required volume of liquid from a storage bottle into an accurately calibrated measuring pipette and by means of a double-way stop-cock, transferring it to the vessel undergoing calibration. The apparatus suggested by Stott[3] (Fig. 1) for calibrating burette tubes is typically illustrative of this method. The following is a brief description of the apparatus.

[1] Received June 30, 1926.

[2] English, *Jour. Soc. Glass Tech.*, **2**, 216, **3**, 34; Stott, *ibid.*, **8**, 38; H. V. E. M. Renn, *Ind. Chem.*, **2** [13], 55.

[3] *Loc. cit.*

A piece of thermometer tubing, *A*, is attached to the top of the burette tube by means of rubber tubing and an adapter. The thermometer tubing controls the rate at which air enters the top of the burette tube and therefore also the rate of outflow of water from the burette. No difficulty will be experienced in selecting tubing which will give a satisfactory rate of outflow. A period of outflow of about 150 seconds (the approximate mean of the limits allowed by the U. S. Bureau of Standards) would be found most suitable, and this must also be the time occupied in emptying the finished burette in practice. The other end, *B*, of the burette is drawn down to a diameter suitable for sealing on the stop-cock when the burette has been graduated and this narrowed end is connected to the apparatus. The stop-cock *C* is opened, *D* and *E* being closed, until a few milliliters of water have entered the tube. The tap, *C*, is now closed and *D* is opened in order to fill the connecting tube so that the lower part of the apparatus is free from air, and also to enable an accurate setting to be made on the lower graduation mark, *F*, of the pipette. The burette tube can now be completely filled and successive intervals of 10 milliliters drawn off into the pipette up the mark, *G*, and emptied to *F*, the same period of drainage being allowed for each interval. The capacity from *F* to *G* can be checked gravimetrically at any time so that the method allows small probability of error.

FIG. 1.

The present writer has found that, in practice, it is advisable to graduate a portion of the tube above and below the mark, *G*, so that, in the event of any change in the capacity taking place, a correction can be made by using some other point on the graduated scale. It was also found convenient to replace the two stop-cocks, *E* and *D*, by one three-way tap.

The fundamental condition fulfilled by the apparatus is the automatic control of outflow, the probability of error due to variation in the rate of drainage, being thus greatly reduced.

The present writer has used a similar apparatus for the calibration of some hundreds of burettes examined at the English National Physical Laboratory. The error limit was at that time only 0.04 cc, which was the maximum error allowed at any point tested and also the maximum difference allowed between the errors at any two points tested. This limit is slightly less than that at present allowed by the Bureau of Standards.

(b) Variation of Bore It is possible to introduce grave errors due to the selection of burette tubing of excessive variation of bore. This has been illustrated by a simple calculation.[1] A variation of only 0.2 mm in the parallelism of the bore of a 50 ml burette tube over a length of 138.2 mm (equivalent to an interval of exactly 10 ml) was shown to give rise to an error of 0.052 ml. This occurs when the method used for dividing or graduating the burette is on the basis of length. A common method of graduating a calibrated interval is to divide the distance between two adjacent calibration marks into a number of equal divisions, or spaces. If any variation exists in the parallelism of the bore, theoretically no two divisions will represent exactly the same volume. If the variation is slight, however, the error introduced will be so small as to be negligible.

In the example given above, the sectional variation was 0.2 mm, so that when the interval was graduated into 100 divisions of equal spacing, a gradual increase in volume would occur at each division from the narrow end of the tube to the wide end. As the spacing during the dividing operation is determined on the basis of the mean volume, it follows that the capacity of the divisions towards the narrow end would be less than the mean, while the capacity of those at the wide end would be greater. Thus, in testing with zero (at the narrow end) as the starting point of each interval tested, the errors of minus value that would at first occur would be eventually cancelled, and when the 10 ml mark is reached the capacity would be found correct. This can be seen by referring to the curve in Fig. 2.

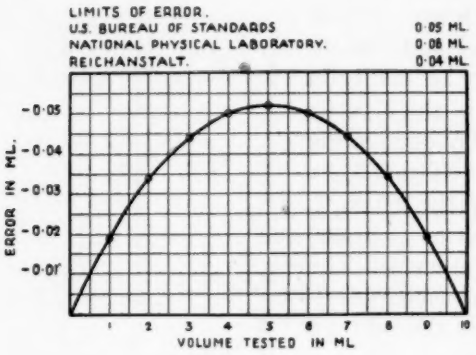

FIG. 2.

It is evident from the foregoing that a burette, correct at the points of calibration, may be in excess of the permissible limit between these points. If the capacity of five intervals is tested and these intervals correspond with the five points of calibration, it is possible that the burette will be certified as correct.

The National Physical Laboratory has lately issued a regulation that burettes are to be tested at any five points and not necessarily at five fixed intervals. This is a significant illustration that the exist-

[1] H. V. E. M. Renn, *Ind. Chem.*, 2 [12], p. 33.

ence of error between the points of calibration is not considered by any means improbable.

(c) Delivery Time Another source of error in burette calibrating concerns the delivery time. The delivery time of a burette is understood to be the time occupied by the unrestricted outflow of water from the zero mark to the lowest graduation. The delivery time of a burette regulates the quantity of water delivered. Again, owing to the drainage of liquid down the walls of the burette, the reading obtained varies according to the time which elapses between closing the tap and taking the reading. Investigations upon this question were carried out by Osborne and Veazey who observed the rise of the water level in a burette after a definite length had been emptied. The amounts of drainage were then plotted against the time intervals. The conclusions of the investigators are summed up in the following extract:[1]

> By limiting the rate of outflow the residue and the afterflow may be made negligibly small. The system of curves considered with reference to the rate of outflow enables a choice of outflow rate which shall sufficiently limit the afterflow. For the maximum or initial rate of outflow a value was sought which should render the residue and the drainage so small that the volume delivered should be independent of such variations and manipulations as are often found necessary by the chemist. Reference to the curves shows that for an initial rate of 0.7 cm per second the maximum drainage from any interval emptied which occurs during the first two minutes after stopping outflow is about 0.05 mm.[2] This initial rate was selected, and the specifications in regard to time of outflow of the total graduated length were so chosen, that on burettes of customary proportions the maximum initial rate should not exceed 0.7 cm/sec.

The existing regulations at the Bureau of Standards, respecting the times of outflow are based upon the observations of Osborne and Veazey.

The delivery time and draining of burettes was made the subject of investigations at the National Physical Laboratory by Stott.[3] A 50 ml burette was used of 534 mm graduated interval and a series of jets was prepared each capable of giving a different delivery time. The results are reproduced in Fig. 3, the amount of water which drained down from the walls of the burette being plotted vertically, and the drainage time horizontally. The delivery times given by the jets used for each set of observations are shown against the curves to which they relate. The drainage was observed after the outflow had ceased.

Reference to the curves will show that when a burette is allowed to deliver its contents quickly the quantity of water draining down

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[1] Bur. Stand., *Bull.*, 1908, p. 584.

[2] That is, a rise of 0.05 mm of the meniscus.

[3] *Jour. Soc. Glass Tech.*, 7, 175 (1923).

the walls is large in comparison with the degree of accuracy required. When the time of outflow was 20 seconds, a volume of 0.24 ml drained down in half an hour, and even in the first two minutes the amount of drainage was 0.07 ml, that is, 0.02 ml in excess of the tolerance allowed by the Bureau of Standards on a 50 ml burette. The delivery time suggested by the writer as suitable for the calibrating apparatus shown in Fig. 1, was 150 seconds, this being the approximate mean of the standard limits. When this time is given, the subsequent drainage is shown by the curves in Fig. 3 to amount to less than 0.04 ml

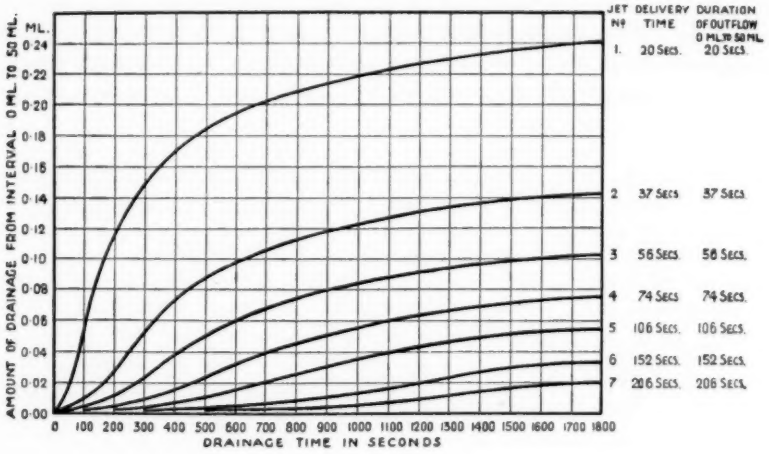

FIG. 3.

in half an hour. The amount of water which drained down in the second minute of the drainage period was approximately 0.001 ml.

The curves amply illustrate the fact that the longer the delivery time, the smaller the probability of error due to such variations and manipulations as are often found necessary in practice. This source of error was also made the subject of investigation by Stott.[1]

A burette of 150 seconds delivery time was emptied in a number of different ways. For example, it was emptied freely from the zero point to the 37.5 ml mark and the tap closed for five seconds. The tap was then fully opened and the water run out to the 50 ml mark. The results obtained by varying this procedure in a number of different ways are shown in the following table.

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[1] *Loc. cit.*

Delivery of burette, 150 seconds
Observed capacity = 49.996 ml = V

Method of emptying	Volume of water delivered, V^1 ml	$(V^1 - V)$ ml
50 ml	49.996	—
37.5 ml + 12.5 ml	50.001	+0.005
37.5 ml + 2.5 ml × 5	50.000	+0.004
25 ml + 25 ml	50.001	+0.005
12.5 ml × 4 times	50.001	+0.005
5 ml × 10 times	49.999	+0.003
2 ml × 25 times	50.014	+0.018
1 ml × 50 times	50.016	+0.020

The same observations were made with a burette the delivery time of which was 31 seconds and a comparison of the two sets of results will show that the liability of error is greatly increased when the delivery time is short.

Delivery time of burette, 31 seconds
Observed capacity = 49.949 ml = V

Method of emptying	Volume of water delivered, V^1 ml	$(V^1 - V)$ ml
50 ml	49.949	—
37.5 ml + 12.5 ml	49.954	+0.005
37.5 ml + 2.5 ml × 5	49.954	+0.005
25 ml + 25 ml	49.956	+0.007
12.5 × 4 times	49.957	+0.008
5 ml × 10 times	49.962	+0.013
2 ml × 25 times	50.003	+0.052
1 ml × 50 times	50.041	+0.092

(d) Incorrect Marking of the Meniscus

Error due to the faulty marking of an accurately measured volume of liquid may arise from the incorrect location of the lowest point of the meniscus, or from parallax. It is evident that an accurate means of measuring a required volume of liquid is useless when it is not coupled with an equally accurate method of locating and marking the position of the water meniscus. When the location and marking is carried out by the eye and hand, unaided by any mechanical device, it is an extremely simple matter to misplace the mark by such an amount as to introduce an error in excess of the tolerance allowed. Parallax, unsteadiness of the hand, uncertainty, general carelessness and "personal factor" will easily account for errors of such magnitude.

A device for the elimination of error due to incorrect location and marking of the meniscus has been proposed by English[1] and is shown diagrammatically in Fig. 4.

A short focus telescope, A, working up and down the stand, B, by a rack and pinion can be adjusted so that the cross-wire coincides

[1] *Loc. cit.*

with the extreme point of the magnified image of the meniscus. With a magnification of three or four diameters, it is an easy matter to make this adjustment very exactly without any possibility of parallax error. When this is done, the position is marked on the tube by means of the needle, *C*, which can be moved forward and horizontally, but not vertically. The needle, which is pivoted near the front of the telescope, is pressed forward until its point meets the tube, and is then moved across the tube thus making a fine mark through the India ink, or whatever medium is used for the purpose. As the point of the needle is in the same plane as the cross-wire of the telescope, it is impossible to place the mark in the wrong position.

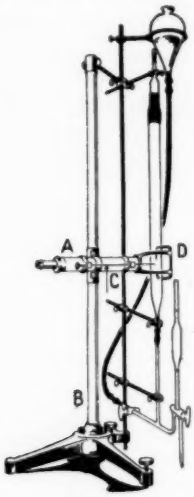

FIG. 4.

It is a well-known fact that in reading a meniscus, the reflections and refractions which occur at the liquid surface and the glass surfaces render the exact location a matter of great difficulty, and that it is necessary to screen and shade the meniscus with some suitable device. Bergmann and Göckell[1] introduced a device that is now universally used in some form or other. It consists in a wooden test-tube holder painted a dull black inside, a square of matt paper being used as a background or screen. The test-tube holder is clamped to the vessel so that its top edge is not more than 1 mm below the lowest point of the water meniscus.

The Bureau of Standards requires the following method of reading:

> In all apparatus where the volume is limited by a meniscus the reading or setting is made on the lowest point of the meniscus. In order that the lowest point may be observed it is necessary to place a shade of some dark material immediately below the meniscus, which renders the profile of the meniscus dark and clearly visible against a light background. A convenient device for this purpose is a collar-shaped section of thick black rubber tubing, cut open at one side and of such size as to clasp the tube firmly.

At the National Physical Laboratory, a strip of black paper is folded round the circumference of the vessel not more than 1 mm below the mark on which the setting is made and held in position by an ordinary paper-clip. The meniscus thus shaded is viewed against a white background.

In the device shown in Fig. 4 when using a telescope for fixing the position of a magnified meniscus, it is not only necessary to use the same screen, but also that this screen should be kept the same distance away from the tube, as a variation in the distance between the screen

[1] *Z. angew. Chem.*, 829, 990 (1900), 4 (1902).

and the tube, very appreciably affects the apparent position of the meniscus. To prevent error from this cause, a screen, *D*, is mounted on a framework which is secured to the telescope tube and thus a permanent background is provided at a fixed distance behind the tube being calibrated.

The device outlined above, used in conjunction with the measuring apparatus suggested by Stott (Fig. 1) successfully eliminates serious errors in the calibrating operation.

(e) After-Working of the Glass A source of error that is not sufficiently recognized is the occurrence of after-changes in the glass during a period immediately following manufacture. The first work to appear on the subject was that of R. Weber,[1] who made observations upon 23 different thermometer glasses with a view of establishing a relation between the after-workings of a thermometer and the composition of the glass.

If a newly-made thermometer is merely exposed to variations of atmospheric temperature the glass gradually contracts, the movement slowly decreasing until it finally ceases. With some glasses variations continue to occur even after a period of years, but the experiments conducted by the present writer upon glass volumetric apparatus show that a period of seven months is usually sufficient in order to avoid excessive error.

The theory put forward to explain the phenomenon of after-working is still open to question. Upon the release of stress, such as would occur in the ordinary process of annealing, an elastico-viscous movement is set up which may extend over a comparatively lengthy period. During the fall of temperature, the walls consist of layers at different temperatures. If these layers are considered, for the sake of argument, to be independent of each other, they would separate from one another, the distance being proportionate with the differences of temperature and with the expansibility of the glass. As soon as the layers have attained a common temperature they will all be in contact and free from stress. As the layers are not independent, however, but are actually united firmly together, it follows that during the fall of temperature, a deformation occurs, the outer and inner layers being under stress, while between the two there will be a layer free from either thrust or pull. The elastic deformations thus produced in the walls during the change of temperature are responsible for the phenomenon of after-working. As a working hypothesis, it has been assumed[2] that there is an alternate inward and outward movement as the results of the two opposite kinds of stress which contend with

[1] Ber. d. Berlin Akad., 1883.

[2] Hovestadt, Jena Glass.

one another. An increase of temperature was chosen for the hypothesis. Upon an increase of temperature, the after-working of thrust in the outer layers first comes into operation. The movement continues beyond the normal equilibrium and the after-workings of pull in the inner layers come into play. The limit of this movement will depend upon the magnitude of the movement itself and upon the elastic resistance of the outer layers. After the movement of extension has ceased, there will be slow recoil, and the after-working of pull finally ceases, but this time without stress in the walls.

It is evident from the foregoing that the minimum after-working is brought about when the conditions are low thermal expansion, high conductivity, and high coefficients of elasticity. Weber[1] concluded from his investigations upon the relation between after-working and composition that the very fusible alkali glasses give bad results. A good result is given by pure potash glasses with large proportions of silica and lime. This conclusion was later confirmed by Wiebe,[2] who showed that after-working is most pronounced in glass containing soda and potash in about equal proportions and that in a potash glass nearly free from soda the after-working was least. The amount of lime ranged from 7 to 14%. The results of experiments carried out at Jena show that, in general, glasses possessing good thermal endurance are least affected by after-workings.

In the experiments conducted by the present writer to determine how after-working affected the accuracy of glass volumetric apparatus, a soda-lime glass was used containing a small proportion of potash. In the first experiment, five flasks of 100 ml capacity were marked with a fine line around the circumference of the neck. The capacity was then computed from the results of three determinations, each determination being carried out by an independent observer. During the seven months that the vessels were under observation, the temperature varied over a range of less than 10°C. Drying was carried out by first rinsing with alcohol and ether and then passing a stream of air through the flask by means of an ordinary filter-pump. The flasks were examined optically for strain and were found to be well annealed. Tests were made each month by three independent observers and the alteration in capacity computed from the mean of the determinations. The results have been recorded graphically in Fig. 5.

It will be seen that in every case a sudden contraction, ranging from 0.006 ml to 0.024 ml, took place in the first month. During the second month the contraction considerably diminished in magnitude, the

[1] *Loc. cit.*

[2] Ber. d. Berlin Akad., 1884.

greatest alteration, 0.008, being observed with the two flasks numbered 2 and 3 respectively. The third month showed that the diminution in volume was still less, flask No. 2 showing the greatest contraction with 0.006. In the case of flask No. 4, a slight increase in capacity was observed. This expansion was noted with four out of five flasks at some time or other during the period of test, the one exception being flask No. 3. Unfortunately, this was broken during preparations for the tests after the fourth month, a fate which also befell flask No. 4 two months later. The slight increase in volume noted in the four cases is most probably due to some experimental condition and the writer would not suggest that the increase was real. It was not until after the fourth month that the curves began to approach more nearly straight lines and it is evident from this that, for the particular glass employed, a standing period of five months before calibration should be the minimum allowed. As a matter of fact seven months was decided upon as the most suitable period.

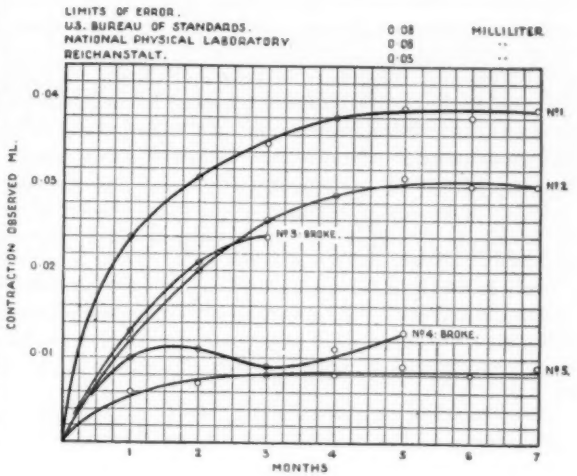

FIG. 5.

A flask can, of course, be graduated during the period of contraction and still be within the limits of error allowed, after the movement has ceased. This is easily possible if the capacity of the flask is slightly larger than intended, for the alteration in volume due to shrinkage would bring about the cancelling of the original error. In cases where the original error is of minus value, however, it is not improbable that the diminution in the volume of the flask due to after-working would cause the error to be increased beyond the permissible limits.

LONDON, W. C. 5.
ENGLAND

REFRACTORIES FOR OIL-GAS MANUFACTURE[1]

H. J. KNOLLMAN[2]

ABSTRACT

The present investigations of refractories by the oil-gas industry on the Pacific Coast were stimulated by sporadic independent tests in the past whereby it was observed that different qualities of fire brick not only had varying lengths of service but also had an apparent influence on the amount and quality of gas made and on the efficiency of gas manufacture.

The essential differences in generator design, including that of brick-work construction, in the two-shell type of generator as compared with the single-shell generator are such that longer refractories life is obtained in the former type. The operations in the manufacture of oil gas for the two-generator types are briefly discussed, showing that the refractories are subjected to alternating oxidizing and reducing conditions.

Other causes contributing to ultimate refractories failures are carbon deposition in the brick, abrasion of hot gases and the impinging of long flames on the brick, heavy checker-brick loads on arches, faulty construction of arches, and erratic working conditions. In addition, super-saturated steam, heavy hydrocarbons, and salts and sulphur in the oil, are contributing causes to checker-brick disintegration, especially in the generator zones where the oil and steam are introduced. It is hoped that specifications for refractories may be drawn up from the results of practical service tests now being conducted.

The heat-transfer and heat-absorption properties of various refractories, such as conductivity, specific heat, density, diffusivity, heat capacity, and time required for the refractories to reach near-heat saturation, are discussed, particular attention being given to their possible application as oil-gas generator checker brick. The need for more complete and accurate data on the fundamental constants necessary in heat-transfer calculations is pointed out.

Researches on refractories with thermal properties superior to fire brick are now being conducted in generators in an endeavor to increase gas capacity and operating efficiency along the lines indicated by theoretical considerations.

Introduction

The important part that refractories play in the process of making artificial gas from crude oil or its residues as carried out in the oil-gas industry is being increasingly realized by the utilities in question. The oil-gas industry, with the exception of a few small installations in the East, is confined entirely to the Pacific Coast, extending essentially from Portland, Ore., in the north, to San Diego, Calif., in the south. For this reason its refractories problems have been of a rather local nature; and since initial cost combined with past performances have been the criteria by which purchases were made in the past, but little attention has been paid to the special requirements of gas-plant refractories.

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[1] Published by permission of the California Gas Research Council. Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga., Feb., 1926. (Refractories Division.)

[2] Ceramic Engineer, Los Angeles Gas and Electric Corporation, Los Angeles, Calif.

This attitude has been gradually changing in the last few years, however, so that more attention is being given to the matter of adapting refractories of distinct characteristics to the purpose for which they are best suited, and to buy on the cost-plus-service rather than on the initial-cost basis.

The condition that has existed in the past may be said to be due in part to several reasons: (1) the quality of the refractories varies sufficiently from time to time to make it difficult or impossible to secure accurate data; (2) the generator operating conditions are not sufficiently uniform to give the refractories a fair trial under any particular conditions; (3) the large variety of generator sizes and their variable dimensions, with consequent variations in operations as found in the different companies of the industry, make it very difficult to obtain systematic and definite refractories data; (4) the grouping together of a number of generators in the same plant, few of which are independent of each other, results in operating figures that give only the average results for the whole plant, and it is therefore difficult to compare the behavior and relative efficiency of one generator with another.

1. First Practical Tests on Refractories

The first concerted effort to pay greater attention to the refractories required was made by the Joint Committee on Efficiency and Economy of Gas of the Railroad Commission of the State of California. This Committee was later reorganized as The California Gas Research Council, under whose direction the present research work of the California gas utilities is being conducted.

The original Joint Committee made extensive researches and plant tests during the years 1920 to 1923 to determine the efficiency of gas production at existing gas plants and under existing modes of operation for the production of different qualities of gas. During the course of these researches the Committee's attention was frequently called to the apparent influence of various fire brick on the amount and quality of gas produced and on the efficiency of gas manufacture. Consequently in their Progress Report of September 15,1 921, the following clause will be found:

> Little is known at the present time regarding the quality of checker and lining brick as adapted to gas generator use. Utilities in the State have found no definite method of determining beforehand the probable usefulness of different bricks. The determination of a practical means of testing fire brick to be used, and the type of brick best adapted to gas use, is to be studied for the benefit of the industry.

This Committee sent out a questionnaire to the principal oil-gas companies requesting data on lining and checker brick, spacing of the latter, and specifications. The answers received showed that there were no specifications, but that there were considerable variations in length of service and in desirable properties of the brick required, with

no accurate data as to the reasons for the variations and differences of opinions expressed.

In order to study the respective merits of different checker brick, this Committee secured fire brick from four different refractories manufacturers, two located at Los Angeles, one at Stockton, Calif., and the fourth at Denver, Colo. These brick were installed in a gas generator at Santa Barbara, Calif., in June, 1922, and were laid straight flue with 2½-inch spacings between the brick, in such manner that each representative brick was allotted a one-quarter vertical section of the total checkers.

Due to some unusual conditions, the operation of this generator soon became very erratic, and it refused to respond to any of the usual methods of regulation and control. Various cycles were run under different variations of blast and heat, the effect of which showed an extremely unbalanced thermal condition of the gasifying zones. Wide variations in the quality of the manufactured gas were obtained, accompanied with difficulty in diffusing the heat from the combustion chamber uniformly throughout the checker brick. On account of the uncontrollable tendency of the generator to cause wide fluctuations in the heating value of the gas, together with an excessive oil duty, it had to be taken out of service after about a month's trial. The unsatisfactory heat conditions for gasifying the oil were attributed to the different properties of the bricks under test. This view was strengthened by later results, when the different brick were used independently in the generators without such untoward results, but with varying efficiencies.

2. Present Investigations of Refractories

The references and conclusions on fire brick made by the Joint Committee aroused such interest in the refractories problem that the California Gas Research Council has continued the investigation as one of its major research projects, working in close coöperation with the committees of the Pacific Coast Gas Association. The Pacific Coast Gas Association has now a Refractories Bureau, with H. L. Masser, Gas Engineer of the Los Angeles Gas and Electric Corporation, as Chairman. This Committee is composed of three subcommittees, known as the Refractories, Checker Brick, and Insulation Committees. The subcommittees at the present time are composed of representatives from the various gas companies and from various interested California refractories manufacturers. Their object and purpose is to make tests and service studies of their respective particular refractories problems, in order that the special requirements of the industry may be determined and be more definitely understood by both the consumer and the manufacturer. Proposed refractories

studies, as well as those already under way, will be discussed at greater length in the latter parts of this paper.

Oil-Gas Generators and Their Operation

There are two distinct types of oil-gas generators in general use: the single-shell or "straight shot," and the two-shell or Jones generator. The latter consists of two cylindrical steel shells or chambers, primary and secondary; whereas the former consists of one cylindrical vertical steel shell. Both types are lined to a greater or less degree with some form of insulation next to the steel, followed by one or two courses of fire brick, which make up the generator side walls.

1. Construction of Single-Shell and Two-Shell Generators

Figure 1 shows the essential construction features of the single-shell generator. The steel bottom is covered with several layers of fire brick, or with insulation and fire brick. There are two long combustion chambers at the bottom of the generator separated by a firebrick center wall with arches overhead. The arches, consisting generally of three separate rings laid one directly over the other, are spaced about 3 to 4 inches apart, thus allowing the hot gases to pass on up between them. They support the mass of checker brick overhead. The checker brick generally consist of standard 9-inch brick, spaced from 2½ to 3½ inches apart in regular checker fashion, thus leaving open checker spaces through which the gases can travel. Above the checker brick is another open space, occupying one-third to one-

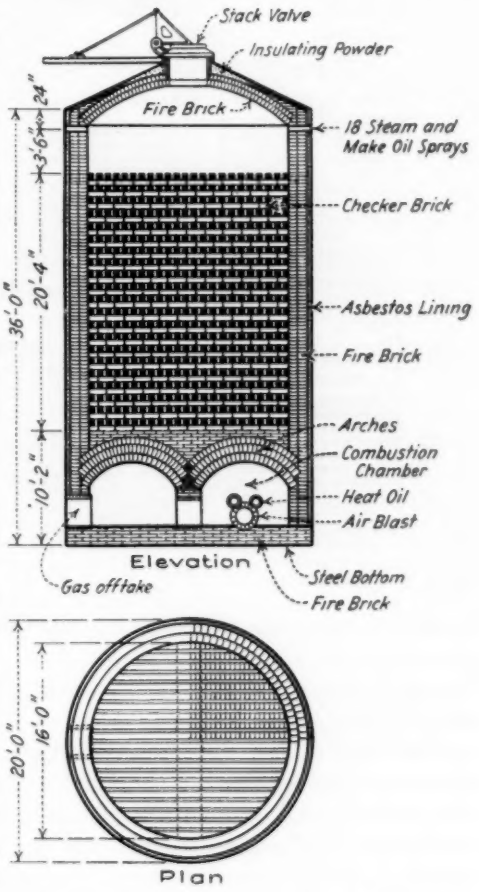

FIG. 1.—20-foot diameter single-shell straight-shot oil-gas generator.

fourth of the interior of the generator, which is the gas-making chamber. The roof consists of fire brick on the inside of the gas chamber, with loose insulation between the fire brick and the steel roof on the outside.

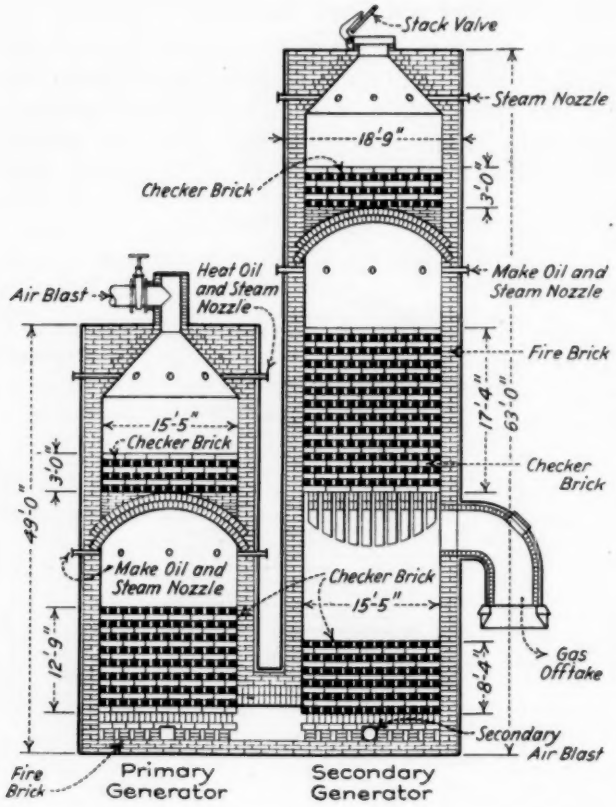

FIG. 2.—18 ft. 9 in.-diameter two-shell oil-gas generator.

Entering the two combustion chambers at the bottom are blast pipes, admitting air for combustion, and burners for conveying the oil for heating. The heating is accomplished by means of a long flame burning throughout the length of the combustion chambers. Entering the upper chamber above the top checker brick are a number of steam and oil sprays for gas-making purposes. On the top is the stack valve, open while heating and closed while making gas.

Figure 2 shows the essential construction features of the Jones generator, where the primary and secondary shells are connected at the bottom with a steel throat piece lined with fire brick. The side walls and bottoms are lined with fire brick and insulation, but the interior arrangement consists of open chambers and bodies of checker brick alternated at different heights in the two shells. Each shell has a body of checker brick on the bottom followed by an open chamber overhead. In the primary shell, arches are built in the upper section of this lower open chamber. These arches support 4 to 6 courses of checker brick overhead. This checker work is then followed by another

open chamber. In the upper part of this chamber are located the heat oil and steam nozzles. The heating up of both shells is accomplished at this point. A stack with air blast completes the top of the primary shell.

The secondary shell has the gas off-take in the first open chamber above the bottom checkers. A large number of checker brick supported by arches with suitable openings between them are located in about the middle of the secondary generator. Then follows another open chamber with provision for make-oil and steam nozzles. Arches are located in the upper section of this chamber, which in turn support four to six courses of checker brick. An open chamber with the stack on top and provision for steam nozzles completes the top of the secondary shell. At the top of the primary shell and the bottom of the secondary shell are inlets where air is introduced.

Single-shell generator sizes range from 5 feet in diameter by 18 feet high to 27 feet in diameter by 43 feet high; while the two-shell generator sizes range from 3 feet 6 inches in diameter, with a rated capacity of 40,000 cubic feet per day to those 18 feet 9 inches in diameter, with a rated capacity of 5,000,000 cubic feet per day. The single-shell generators have a rated capacity ranging from 100,000 cubic feet to 5,000,000 cubic feet per day. The largest size of both types of generators requires in the neighborhood of 60,000 standard 9-inch checker brick.

2. Operation of Single-Shell and Two-Shell Generators

The gas-making operations, while essentially the same, vary considerably in the two types of generators, principally due to the fact that more water gas is made in the two-shell generator. The heating and gas-making periods of the cycle also vary with the size of the generator so that the operation of an average-size generator of each type will be briefly discussed.

In the average-size single-shell generator the stack valve is opened at the end of the make period; the air-blast valve at the bottom is then opened and air turned into the generator. This part of the cycle, known as the dry blast, lasts from one to three or four minutes, and often is accompanied by long flames through the checker work. The operator dry blasts the generator in order to clear it of waste gases and to burn away excess carbon deposited on the checker brick from the previous run. He next turns on the heating oil, which is sprayed into the bottom combustion chambers where, mixing with the air, it ignites and burns with a long flame, the hot gases meanwhile passing up between the arches and through the checker brick and making chamber, finally leaving through the stack. This part of the cycle usually lasts from 9 to 12 minutes. The dry blast and combustion period together constitute the heat period. The checker brick are thus heated to an average temperature of 1700°F.

Following the heat period, the blast and stack valves are closed, and then oil mixed with steam in a finely divided state, which is generally preheated to a few hundred degrees, is sprayed through the injector nozzles into the making chamber at the top of the generator. Upon striking the heated checker brick, the finely atomized oil and steam are converted into gas. The gas passes down through the checker brick and leaves the generator through the off-take pipe at the bottom of the generator, whereupon it then goes to the washbox and remaining purification processes before finally reaching the gas holder.

This conversion of oil and steam to gas lasts for about 15 to 25 minutes, when the checker brick have then become so cold that they must be reheated. The generator is then purged for 5 to 10 minutes with steam so as to drive out the remaining gas left in the generator after the oil valves have been closed. This purge period combined with the period of conversion of oil to gas is known as the make period of the cycle.

In the two-shell generator the gas off-take valve is closed and the stack valve opened at the end of the make period, whereupon the operator then turns on the air blast at the top of the primary generator. This dry blast, lasting for a few minutes, clears the generator of the waste gas from the previous run and burns the carbon on the checkers. The heat-oil and steam-nozzle valves located in the upper chamber of the primary shell are then opened, whereupon the superheated steam and oil mix together through the burners, the steam breaking up the oil so that the mixture of the two is in a finely divided state. The oil-steam spray mixes with the air introduced by the blast through the stack and ignites, so that combustion rapidly takes place. The hot gases pass down through the primary shell, across through the throat connection and up through the secondary shell. The waste products of combustion finally pass to the atmosphere through the secondary shell stack. The heat period, together with the dry blast, lasts for about 10 minutes, heating the checker brick to an average temperature of 1600 to 1700°F.

The generator is then ready for gas making. The operator first closes the air blast, then opens the off-take valve and closes the stack. Then for about a minute he turns steam into the upper open chamber of the secondary shell. Next he opens the valves which allow the steam and oil to flow through the nozzles. The oil, usually preheated, is sprayed upon the heated checker brick, whereupon it is immediately changed from liquid to gas. The steam combines with the oil gas, similar to a water-gas reaction, to form the manufactured gas. Gas making goes on in both shells of the generator at the same time. From the open chambers, into which the oil and steam are sprayed, the gas passes

between the hot checker bricks to the off-take chamber. It travels down through the primary shell, across the throat connection, and up to the off-take, while on the secondary side it travels down from the making chamber to the off-take below. This conversion of steam and oil to gas lasts from 8 to 10 minutes. The generator is then purged for a few minutes with steam in order to drive out the remaining gas left in it, and it is then ready for the dry blast.

3. Alternating Oxidizing and Reducing Conditions

From the nature of the process, it will be seen that both the arch refractories and the checker brick are subjected to alternating oxidizing and reducing periods, in which the latter condition strongly predominates. During the heat period, the gases may become highly oxidizing. An average gas analysis taken near the end of the heat period is as follows:

CO_2 13.0 O_2 2.0 N_2 85.0

During the make period the refractories are not only subjected to a large amount of finely divided carbon particles, but also to the intense reducing gases made during this period. The following may be considered a typical average analysis of the manufactured gas after its purification:

CO_2	2.0	CO	10.0
C_nH_{2n}	1.5	CH_4	40.0
O_2	0.2	N_2	1.5
H_2	45.0		

Due to the regular cycles of operation of the generator, the heating and cooling of the refractories is in regular cycles, but at irregular rates. The temperatures within the generator and the rate of the temperature rise and fall is not known to a high degree of precision. This is mainly due to the fact that serious difficulties are encountered in making temperature observations within the generators themselves. The heavy deposits of carbon, and the intense reducing gas conditions, especially at the higher temperatures encountered above 1700°F, alter the potential of both base-metal and rare-metal thermocouples in a very short time. High-duty alloy steels are required for protection tubes, and even they are permeable to the gases and have a rather limited life under the deposition of carbon and strong reducing conditions of the gaseous atmosphere at these higher temperatures. The problem of suitable pyrometric equipment for use in oil-gas generators with a reasonably long life and accurate temperature readings for long periods of time is not as yet completely solved.

Refractories in the Combustion Zone of Generators

1. Comparison of Life of Refractories in Two Generator Types

Some of the refractories, such as those used for the dome arches, stack nozzles, and side-wall linings, are under such comparatively mild working conditions that their repairs are insignificant, and they have an almost indefinite life in all generators. The refractories for arch use are under much more severe conditions, however, particularly in the single-shell as compared with the two-shell generators. Not only are the former subjected to excessive flame conditions, due to the large amount of checker brick overhead that have to be heated during the heat period of the cycle, but they are also subjected to a much greater load than similar refractories for arch use in the two-shell generators. In the one case, the refractories subjected to intense heat conditions carry practically no load, while in the other case the arches are subjected to intense heat, and also support the entire column of checker brick used in the generator. Failure of the arches in the latter case causes the entire checker work overhead to fall in, so that the refractories requirements are rigid under such conditions.

Information submitted by the various gas companies in a questionnaire have shown that not only the refractories but also the checker-brick life have been much longer on the average in the two-shell type of generator. The life of the checker brick in a single-shell machine averaged about 18 months as compared with 30 months in the two-shell type. The difference is largely due to the failure of the arch brick, causing losses in the checker brick, either from the arches falling down or from the handling losses of the checker brick when new arches have to be installed. In general, the companies using the single-shell type experience more trouble with the arches than with the checker brick. Because of this, particular attention is being paid to the refractories requirements for arch use as found in the single-shell type of generator.

2. Refractory Requirements in the Combustion Zone

The refractories located in the fire boxes of the single-shell generators are therefore subjected to the most severe conditions. In general, the temperatures are not excessive, that is, the average temperatures are greatly under 3000°F. Unfortunately, however, the temperature is generally not uniformly distributed, so that the refractories in some sections of the fire box are subjected to excessive localized overheating and to flame temperatures, while other sections are favored. Uneven or excessive heat distribution is also caused by forcing the generator to utmost capacity during peak demands for gas, or to accidental causes such as fallen checker-brick

sections overhead. Some of the refractories are therefore subjected more or less regularly to a flame temperature exceeding 3000°F, so that brick of high refractoriness are then required.

In many instances improvements in burner design or in location of burners in the fire boxes are of distinct benefit in increasing the life of the refractories. The burners are often so situated that their flame plays directly upon some section of the arches or side walls, particularly under forced conditions whereby the flame length is materially increased, with the result of excessive glazing, spalling, or actual melting at that point. Equalizing the temperatures in the combustion chamber and preventing the flame from being continuously in contact with the refractories during the heat period results in distinct economies. Inspection of various generator fire boxes has plainly revealed these conditions, showing where some of the side-wall and arch brick are heavily glazed and partially melted; whereas in other sections where the flame never comes in contact with the fire brick, they are but little affected beyond surface discoloration, even after months of service.

Where long exposed to excessive flame action, failure of arches results. If an arch has been partly burned away unevenly so that it is thin on one side while the other side retains its original thickness, its stability is endangered so that a collapse is threatened. This would be more noticeable and pronounced were the arches constructed of but one circle of brick; but since three circles are generally used, the upper ones help to carry the major portion of the load and are exposed to much less rigid heat conditions, so that failure of arches is rare. The factor of safety is thereby very materially increased.

The rise of the arch is also a matter of importance. The tendency in recent years has been to increase this rise, so that a rise of 20% of the span is now found in the larger and newer generators. The radius of curvature of the inside of an arch is commonly made in a great many furnaces equal to the span, which makes the rise equal to 13.4% of the span. Several instances have been recorded where arches have collapsed with the entire checker work overhead when too flat an arch was used. Because of the uncertainty of the various factors involved, a considerable factor of safety in arch construction is deemed advisable, which is obtained by the common practice of high arch rises and multiple circles of the arches.

This manner of construction has, to a large extent, prevented deformation of the arch brick due to softening under heat. Any excessive glazing and softening of the brick is confined almost altogether to the lowest circle; and since the other two circles still carry the major portion of the load, plastic deformation of the refractories is not greatly in evidence, even though excessive glazing or melting, so that the brick

start to drip, may have taken place on the lower circle. In fact, repairs are invariably necessary on the lower circle of arch brick only, while the upper circles may last several years before it is necessary to completely remove them, the exact length of service depending largely upon the severity and extent of use during the comparatively short winter seasons. The center and side walls in the fire boxes are so large and massive that they do not need serious consideration, even though portions of the walls may be subjected to severe conditions of use.

3. Spalling Spalling of refractories in oil-gas generators is a matter of practical concern and often is of more serious consequence than refractoriness. In many instances, severe spalling takes place, and it is generally greatest where the temperatures are the highest. Owing to the intermittent nature of the generator operation, whereby the refractories are rapidly heated up during the heat period and are then cooled during the gas-making period, favorable spalling conditions are present. The long oil or gas flames impinging only at periodic intervals on the refractories present a severe condition, difficult to overcome. Add to this the alternating comparatively short oxidizing conditions during the heat period, followed by intense reducing conditions for a much longer period of time, and it will be seen that most favorable spalling conditions are present, which are a serious factor in affecting the ultimate life of the refractories.

The refractories absorb a large amount of finely divided carbon under the reducing conditions, which, upon being oxidized, expands in volume, tending to disrupt the brick. Moreover, the action of the reducing vapors on the fire brick brings about a volume change on the exposed portions of the brick by causing incipient vitrification. Such fire brick become glassy and changed in character, due mainly to a reduction of the fluxes in the brick, so that reduced silicate slags are formed. The result is a cracked brick surface or spalling, which has a weakening effect on the entire arch structure. The brick pieces fall to the floor, and the margin of utility of the brick in the arch is materially lessened. Examinations made of badly spalled brick have readily disclosed sections of the same brick in various stages of incipient vitrification, accompanied by cracked brick surfaces.

A common practice that partially overcomes this condition is to wash or paint the brick surface with a mixture, such as common salt or clay, that will fuse and glaze the surface. The pores are thus sealed so that the reduced gases are not so readily absorbed. Although lowering their refractoriness somewhat, this is confined to the outer section of the brick and is preferable to the excessive spalling otherwise taking place. This practice is extensively employed in the industry with greatly improved results, although more refractory glazes, which have

a melting point as high or higher than that of the brick themselves, are now being tried out in tests. A refractory glaze coating, sealing the pores but containing only enough fluxing material to attack slightly the surface of the brick upon which it is applied, so that it becomes practically a part of the brick, gives evidence of being much more desirable.

4. Causes of Refractories Failures The principal causes of destruction of fire brick under operating conditions are the deposition of carbon within the bricks from the volatile hydrocarbons, the abrasion of hot gases and impinging of long flames on the brick, expansion and contraction of the brick due to sudden temperature changes, and in some instances the pyrochemical action of solids, salt water, sulphur, etc., present in the oil. Often also a generator which has been lying idle for a considerable period of time is suddenly pressed into service at maximum capacity. This is a condition that has to be contended with during the winter seasons in order to meet peak gas load demands.

5. Final Selection and Construction Factors Involved In general, the most suitable firebox refractories are low in fluxes so that their refractoriness is increased; heavily grogged, of coarse grain, to reduce spalling; and preferably fired to a high temperature to reduce danger from excessive shrinkage and cracking later in use. Where not exposed to flame conditions a moderately refractory fire brick serves adequately, particularly for generator sidewall use.

The value of having skilled workmanship in laying up the refractories is, in general, fully realized. Badly laid masonry results in the best of refractories having an inferior life, as has been demonstrated by actual failures. Fire brick, especially for arch use, must be true to shape—a requirement to which special attention is being given. Deformed brick with high or low spots take unequal stresses when in use and are subject to cracking because of undue strains on the high points. The brick are commonly set rubbed in place, and if mortar is used between them at all, they are dipped in a thin refractory fireclay mortar. Thick mortar is now quite generally avoided in the industry, and much better results are obtained by using the mortar very thin and by using a fire clay or a mixture of fire clay and finely ground grog of refractoriness equal to that of the brick themselves. Since the sizes of arch brick in general use are special wedges, usually nine by six inches, with varying maximum and minimum thickness, not much cutting is necessary, and this is avoided as much as possible. Considerable attention is paid to proper workmanship by skilled masons, well versed in laying up refractories.

6. Present Service Tests Some practical service tests are now being conducted in an actual generator in preference to depending upon the results of laboratory tests. The problem of the specification of refractories in the combustion zone of a generator is a difficult one because no laboratory tests are available which in any way serve to give a comparison with that obtained in commercial operation. The available load tests, water or air spall tests, shrinkage and high-melting-point tests, are inadequate, inasmuch as it is almost impossible to obtain the gaseous atmospheric condition that is present in the generator during the processes of gas-making. A modified load test is misleading and inconclusive, since the temperatures under normal operating conditions are so variable and are generally lower than called for by the test, and the loads are also variable in different sized generators. The most conclusive test is, of course, secured by actually installing the various refractories in the generator arches, and having them carry the normal checkerbrick load overhead.

Several Pacific Coast refractories manufacturers have submitted their representative fire brick for test, and these have been installed in a large generator at the plant of the Los Angeles Gas and Electric Corporation under normal operating conditions and normal loads. The brick for the test were as uniform in shape as was commercially possible to make them, and they were laid up with very thin dipped joints and rubbed in place.

Since the temperature distribution in the fire boxes is so variable and the upper two rings of any particular arch are under less severe conditions, the upper rings were constructed of one manufacturer's product only; but the lower ring of all the arches in this test generator was laid up with all of the different representative refractories, in regular rotation, so that the various fire brick are being given as nearly as possible the same service conditions. All representative brick under test are therefore being given equally severe to equally moderate service conditions. A careful record is kept of the exact location of each brick. This generator is now in continuous operation, and the necessary manufacturing data is being recorded for later use in correlating results. After the present winter's run, the generator will be laid out, the brick carefully examined, and their respective condition in the various sections recorded for further use.

Several mortars of quite widely varying properties, as well as glaze coatings on the surface of the brick that have been used to prevent spalling in the past, are included in the test. By correlating the service results with the properties, composition, method of manufacture, etc., of the various refractories under test, it is hoped to obtain sufficient data so that specifications for refractories for future use can be drawn

up. It is proposed to extend this study to brick of widely varying characteristics and to those manufactured in other localities should the wisdom of such a course be indicated or appear necessary, supplemented by such laboratory tests as will indicate limits of use.

Refractories Requirements in Connection with Generator Insulation

Proper insulation of gas generators in order to prevent heat losses, firing out of steel bottoms, and the like, is claiming the attention of the industry to a constantly greater degree. It is not a matter of special interest here, except as it affects the refractories used in this connection or is affected by them. The usual manner of insulating generators is to employ materials of low conductivity, such as infusorial earth, magnesia, fire felt, glass wool, light-weight refractories, and the like, next to the steel shell, followed by one or more courses of fire brick of good quality.

Since considerable pressure is exerted within the generator against its side walls and exterior during the gas-making operations, the problem of obtaining gas-tight walls is a matter of considerable concern, especially if but one course of fire brick is used and the insulating materials deteriorate at comparatively low temperatures. The opening up of joints, both between the refractories and insulating bricks where the latter are used, largely destroys the effectiveness of insulation, since the hot gases then penetrate through these joints and heat the steel shell, allowing large heat losses. The use of truly non-shrinking, high-temperature cements between the fire brick in order to render the wall as nearly monolithic and gas-tight as possible is a necessity, in which good workmanship in laying the wall also is a large factor. Not all opening up of joints is eliminated by their use under all conditions, owing to the expansion and contraction of the generator walls with variable working conditions, such as frequent temporary shut-downs, variable temperatures in the generators, and the like, but the degree of heat loss is very materially reduced. In a number of instances the use of insulating materials has been rendered rather ineffective due to the opening up of numerous joints in the brick work, especially where excessive quantities of high-shrinking, fireclay mortars were used between the bricks. Close attention to this factor is a necessity if satisfactory results are to be obtained.

Another factor of some influence is the penetration of carbon in the pores of the fire brick. In extreme cases the penetration may become very heavy, or heavy hydrocarbons may be absorbed so that the brick have the appearance of being oil soaked. In certain instances they become oil soaked from direct leakage of oil onto the brick. This carbon penetration reaches the insulating materials, and when it

becomes excessive the insulating value of these materials is materially reduced. Dense, hard-fired brick are more effective than soft, porous brick in resisting this penetration of carbon and carbonaceous compounds, so that fire brick of a dense nature are here best used.

Checker Brick

1. General Checker-Brick Considerations The checker brick used in oil-gas generators assume a position of great importance, for in many respects they are the heart of the process of converting crude oil or its residues to artificial gas. The heat absorption, conduction, and heat-transfer properties of the checker brick used play a large part in the efficiency of the process. Interesting and important as are these properties, the physical properties of the brick, such as fusion point, mechanical strength, load-carrying ability, resistance to spalling, cracking, and disintegration, must be given first consideration.

A study of checker brick that have been in continuous use for some time in the average-size generator indicates that they may be roughly divided into two classes: (1) those that tend to become porous, fragile, and weak; and (2) those that become dense and vitreous. The most porous and fragile brick are usually found in the upper courses, whereas the most vitreous, often to the extent of being partially melted, are naturally found nearest the combustion zone. This distinction is not sharp nor well defined; and the upper, more fragile brick often become quite dense due to the fact that the temperatures are sufficiently high to cause partial vitrification of the clay, whereas the oil and steam have exerted a disintegrating influence.

In the single-shell generator, the first few courses just over the arches, and the first few upper courses under the oil and steam nozzles and injectors, bear the brunt of severe operating conditions, but in an entirely different manner, whereas the middle section of the checker work is the most favored. The lowest checker brick must withstand the more severe temperature conditions—at times nearly as severe as the arch brick refractories—and in addition must stand heavy loads, since they support the entire checker-work structure. This does not hold true, however, in all cases for the lower checker brick in the two-shell generator, since they are often far removed from the combustion zone and also do not carry such heavy overhead checker-brick loads. The upper checkers, on the other hand, while under more moderate temperatures, are subjected to quite rapid temperature fluctuations, carry no load, and do the bulk of the conversion of oil to gas, especially at the start of the make period. The middle checkers are under the most favorable operating conditions, since they are free from either one

of these extremes and so are most moderately affected during their life in the generator. The upper and lower checker brick must also stand up under abnormal conditions, especially when the generators are forced to meet peak winter load demands. They must therefore be resistant to such conditions as excessive heat, action of steam from leaky injectors, excessive oil, and the like.

2. Lower Checker-Brick Requirements In the single-shell generator, the checker-brick courses immediately over the arches must be nearly as refractory as the firebox refractories and, in addition, must be considerably denser and stronger. Owing to their remoteness from the combustion zone, they are not subjected to severe spalling conditions and so need not have an open structure but rather should be dense and well bonded in order not to warp excessively. Observations on the lower two or three courses of checker brick just over the arches have shown two general classes: (1) those that are so refractory that they glaze with difficulty but warp more or less severely, accompanied with opening up of cracks on the bottom side; (2) those that glaze readily, but do not warp to any extent and show but few cracks. The warping and accompanying cracking of the former class was not primarily due to low refractoriness, but invariably was found to be in the more refractory brick that were composed of hard refractory particles of clay or grog, bonded together with a comparatively small amount of fine-grained bond clay. The latter class, while generally considerably less refractory, were machine made, with little or no grog or coarse clay particles, and so were mechanically stronger under the heat and load conditions and therefore less subject to warping. The ideal brick for this use is a hard-fired brick of a highly refractory nature, bonded with a large amount of fine-grained clay. Since the brick are laid on edge, with a checker spacing 2½ to 3½ inches apart, the transverse strength of the checker bricks used in this capacity must be high. Owing to the importance of their location, brick for this particular purpose demand considerable attention, especially with the increasing tendency to use more expensive checker brick in the generator.

3. Upper Checker-Brick Requirements Since the upper checker brick are subjected to such destructive agents as oil and steam, together with carbonizing or reducing gases, the tendency toward opening up and weakening of the brick structure is pronounced. Super-saturated steam, heavy hydrocarbons, salts, and sulphur in the oil, all have a deleterious action due to chemical reactions or mechanical action on the checker brick. To best withstand the action of these destructive agents, the most desirable brick to use is one that is as dense as is consistent with freedom from cracking and spalling

with the temperature changes encountered. Practical experience has shown that soft-fired, porous brick are much more apt to become brittle, weak, and crumbly, with tendencies toward disintegration, when used as top checkers, than the harder fired, denser brick. A compact outer surface is therefore the best protection against rapid deterioration, provided spalling or cracking does not take place.

Superficially deposited carbon, so far as can be determined, has not been particularly harmful to checker brick unless it becomes so heavy as to close up the air spaces between the brick, thus interfering with or shutting off the path of travel of the gases in the checkers. Also since carbon is a poor conductor of heat, such heavy deposits may become a serious hindrance to the heating up of the checker brick, for unless the carbon is sufficiently ignited to burn away, the brick will not heat up readily.

4. Interest in Heat-Transfer Properties of Refractories

The various requirements discussed apply in the greatest degree to a rather small percentage of the total number of checker brick used where rigid conditions demand special consideration. The chief purpose of the checker brick is to provide a rapid absorption and storage of the heat traveling from the combustion zone so that they may be able to utilize this heat for the conversion of oil to gas when the process is reversed. The heat-transfer properties of various fire brick have therefore more recently attracted a large amount of interest.

This interest was largely stimulated by the results obtained by the Pacific Gas and Electric Company in one of their small generators when using Carborundum brick as checkers. At one of their small plants increased gas capacity was a quick necessity; so a small generator, one less than four feet in diameter, was checkered with Carbofrax brick instead of the usual fire brick, whereupon greatly increased gas capacity was secured, sufficient to relieve the immediate shortage of gas. Some other factors had been changed somewhat, so no exact figures were available as to the direct increase in capacity secured through the use of these brick. About one cubic foot of gas per brick per minute was secured, which was considered to be an outstanding event in gas manufacture. The brick remained intact under several months' operating conditions, the upper course only showing some deterioration by having rounded corners and edges.

Another factor arousing interest in the possible use of refractories with greatly improved heat-transfer properties as compared with average fire brick in the relation of these properties to increased gas-making capacity is that of climatic conditions. Owing to the peculiar weather conditions on the Pacific Coast, particularly in southern California, the peak winter load demand is confined to a few months—

in fact some years to a few weeks—as compared with the long winters in other parts of the country. Thus at the plant of the Los Angeles Gas and Electric Corporation there are at the present time 42 single-shell generators ranging from 20 by 30 feet to 27 by 43 feet in size. All these generators are pressed into service, sometimes at considerable overloads, for perhaps only a few weeks of the coldest weather when the heavy demand for gas must be supplied. One-half to two-thirds of the generators are more or less intermittently in operation for about 4 months, while the rest of the year the demand is supplied by 4 to 8 generators. With the rapid growth of these communities the peak demand for gas (of short duration), constantly increases, so that the ratio of excess generators that have to be built, idle most of the time, correspondingly increases. If, however, increased gas-making capacity can be secured by the use of checker brick of superior thermal properties, even at greatly increased initial costs of the brick, the necessity of building a large number of excess generators would be largely relieved. Refractories of high initial cost must have a long life in the generator, however, as well as superior thermal properties, in order to justify their use.

5. Heat Transfer in a Generator

The transfer of heat from the hot gas to the brick and from the brick to the cold oil and gases takes place by the usual three ways: radiation, convection, and conduction. Except for the presence of soot and carbon, the transfer of heat by radiation is very small, since the surface resistance of the gases is small. Transfer of heat by convection is probably not an important factor owing to the fact that the average temperature of the brick surface is lower than that of the hot gases passing by during the heat period, while during the make period the reverse is true, so that the two tend to equalize each other. Conduction is the most important factor, since the transfer of heat from the gases to the brick, from the brick to the oil, steam, and gas, as well as from the surface of the brick to its interior, takes place by conduction. Thermal conductivity is, therefore, an important property of the checker brick.

6. Thermal Conductivity of Refractories

Although many factors affect the thermal conductivity value, such as the raw materials used, impurities present, method of manufacture, density, temperature of firing of the brick to be tested, as well as the temperature of conductivity measurement, accuracy of thermal-conductivity apparatus, and methods used in making the determination, the most important of the factors mentioned in the practical application of the refractories to checker use are those of temperature of the conductivity measurement and density of the brick. Because of these many variable factors and the difficulty in making

true coefficient-of-thermal-conductivity measurements, the multiplicity of thermal-conductivity values that have been obtained is confusing. A search of the available literature reveals a large number of thermal-conductivity values for various refractories that are not only very confusing but contradictory in many instances. It then becomes very difficult to select conductivity values for heat-transfer calculations; and yet accurate thermal-conductivity values are of far-reaching importance in their influence on heat transfer and calculations of problems connected therewith.

The consensus of opinion of many investigators on the thermal conductivity of refractories is that the greater the density of the brick the higher is its heat conductivity, so that apparent density serves as a crude index of the conductivity. It appears, therefore, that a dense checker brick is much to be preferred, not only because of its resistance to deterioration with use in the generator, but also because of its superior thermal conductivity and superior heat-transfer properties. In accordance with these views particular attention is now being paid to this type of checker brick. Much denser and harder fired fireclay checker brick are now under trial in generators in order to determine their resistance to spalling and disintegrating influences, since there is some doubt as to their ability to withstand the operating conditions as well as the more open porous type. Although not having been particularly realized in the past, it is now recognized that whatever can be done to increase the density and heat conductivity of the checker brick will increase its value in use.

Since the conductivity of a refractory is not the same at all temperatures, usually increasing with increase in temperature, thermal conductivities of refractories at the higher temperatures are of special interest. There is, however, a scarcity of data on the thermal conductivity of various refractories at the higher temperatures, particularly above 1500°F, or at oil-gas generator temperatures, so that much remains to be done in this connection.

7. Diffusivity of Refractories

The rate at which heat is stored up in a brick depends not only upon its thermal conductivity but also upon its diffusivity, density, and specific heat, as well as upon the thickness, shape, and dimensions of the brick. Since conductivity values alone apply only when the heating is constant over a prolonged period so that a state of equilibrium is reached, which is not the case in the generator with its operating cycles, the conductivity must be divided by the product of the apparent density and specific heat in order to show the extent to which the heat will be diffused through the checker brick. Since the rate of heating of the interior of

the brick is proportional to the factor $\frac{\text{conductivity}}{\text{specific heat} \times \text{density}}$, or diffusivity constant, it largely determines how much heat will be stored in a brick in a given time, and is therefore of great importance.

High thermal conductivity and high diffusivity (and therefore high density and high specific heats) are consequently all very desirable in checker brick in gas generators where the cycles of heat-to-make and back again are rapid. The importance of high density has already been considered, which applies equally well to the apparent density. Specific heats of various refractories, particularly at the higher temperatures, are not generally available, however. In fact, the scarcity of specific-heat determinations on refractories at high temperatures is much more pronounced than that of thermal conductivities. But here also accurate knowledge of specific heats is necessary for accurate heat-transfer calculations. In view of the importance of these constants to all the industries using regenerators, or the regenerating principle, this subject is one worthy of considerable attention by the Refractories Division of this SOCIETY, the American Refractories Institute, and others interested. A more accurate knowledge of the variables influencing the specific heats, as well as the determination of the numerical values themselves, would be of great benefit to the users of these refractories in their efforts to predict beforehand what such refractories used as checker brick would do when placed in actual service. The Mellon Institute has recently made a beginning in this direction in its work on refractories for use in regenerators, but much more data is desirable.

8. Heat Capacity and Heat Absorption of Various Refractories

The heat capacity of a brick represents the maximum amount of heat that it will absorb, which depends upon its density, specific heat, surface area, thickness, and the temperature difference of the brick surface and its initial temperature. The heat capacity per degree temperature difference per unit area of a fire brick is equal to its apparent density times its specific heat times the brick thickness when heated from all sides. It therefore determines the quantity of heat that a brick is capable of absorbing. Obviously high heat capacity, possessed to a fairly high degree by fire brick, is a very desirable property in checker brick.

Theoretically the time required for any brick to attain a constant uniform temperature is infinite. The heat flow is extremely slow, however, as the brick approaches saturation. The time required to absorb a given proportion of the maximum amount of heat possible can be calculated, as has been shown by O. A. Hougen.[1] Thus, Prof.

[1] O. A. Hougen and D. H. Edwards, "Heat Transfer," *Chem. Met. Eng.*, **29**, No. 18, October, 1923.

Hougen's series exponential formula can be used to calculate the amount of heat absorbed by various refractories per unit area at various time-intervals when heated from two sides at a constant temperature. The most desirable time-interval between gas reversals for checker brick of given material and thickness can thus be obtained. Additional calculations, as shown in the article cited, can be applied to give the total heat absorbed per unit volume and for the total volume of the generator. This total heat is dependent upon the heat capacity of the brick used, the thickness of checker wall, spacing between bricks, and the nature of the checker-brick construction.

Although some improvements can be made in the gas-making capacity of fireclay brick by increasing density, refractoriness, etc., yet the possibilities in the use of other types of brick which are superior in one or more heat-transfer properties are being investigated. Such refractories as silica, magnesite, zirconia, bauxite, diaspor, chrome, as well as the super-refractories: Carborundum, fused magnesia, fused spinel, and fused alumina, are all available for consideration. Since all are more costly than fire clay, the super-refractories very much so, their use appears to be limited to those purposes where they will give far superior service. Of these, zirconia, diaspor, and bauxite brick have a lower conductivity than fire clay, without greatly increased heat capacities, which, combined with their cost, does not make them particularly attractive. Chrome brick are costly; no figures are available as to their specific heat, and the thermal conductivity is not accurately known, except that the conductivity is higher than that of clay and lower than that of magnesite brick. It is therefore difficult to consider their value in this connection. This leaves magnesite, silica, and the super-refractories for active consideration.

In a paper[1] presented at the 32nd Annual Convention of the Pacific Coast Gas Association, Portland, Oregon, August 17–21, 1925, the writer assembled some data on the thermal properties of these various refractories, based on the best data available and on general averages in some cases. These thermal properties, at an average temperature of 1700°F, are given in Table I. The heat capacity values and the time required to reach 95% saturation, which time represents the longest desirable period for reversal of the cycle, are given in Table II and are based upon calculations made by the use of the formulas in the article[1] by Profs. Hougen and Edwards. The values in Table II are also plotted in Figs. 3 and 4. The longest desirable period for reversal applies particularly to the heat period, since the make period is

[1] H. J. Knollman, "Some Refractories Problems in the Oil Gas Industry," *Proceedings Pacific Coast Gas Association* Vol. 16, 1925.

governed largely by the rate of gas manufacture during the cycle.

Figure 3 shows the time required to heat refractories of various thickness to 95% saturation; Fig. 4 shows the heat absorbed by various refractories 2½ inches thick at various time-intervals when the average temperature is 1700°F. The curves vary considerably, depending upon the constants listed in Table I. Sil-O-Cel appears on these curves in order to show its value as an insulator and why it should be avoided for checker use, even if it were refractory enough for such use. These values have their limitations, not only because of lack of accurate knowledge as to their conductivity, specific heat, the average temperature assumed, and the variation in these properties with temperature, but the heat-flow calculations are also affected by the heat-transfer coefficient of gas to brick, the surface resistance of the gas film in contact with the brick, and by the assumption that the heat is flowing in from two parallel sides only, an assumption very nearly, but not strictly, true. The values obtained, however, represent relative values of the various refractories with regard to their different thermal properties so that some predictions as to their probable action in their relation to the manufacture of gas can be made.

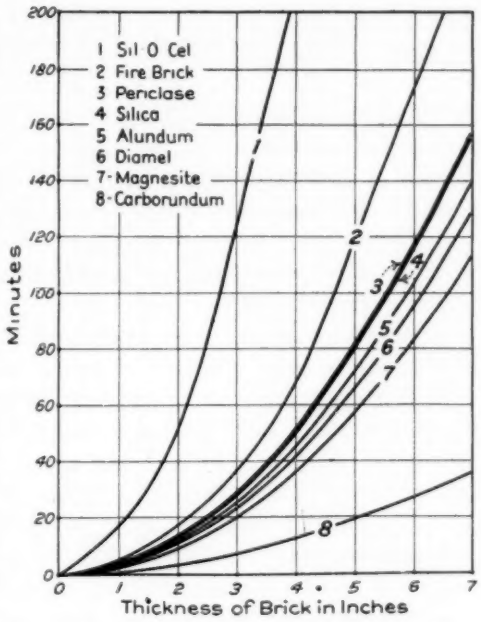

FIG. 3.—Time required to heat refractories of various thicknesses to 95% saturation.

TABLE I

THERMAL PROPERTIES OF REFRACTORIES

Material	Conductivity Gm/cal/sec/units	Apparent density	Specific heat	Heat capacity per unit volume per degree temp. diff.	Diffusivity
Fire brick	0.0034	1.905	0.245	0.467	0.0074
Silica	0.0040	1.56	0.265	0.413	0.0097
Magnesite	0.0095	2.60	0.273	0.710	0.0134
Periclase	0.0080	2.80	0.290	0.812	0.0099
Alundum	0.0065	2.45	0.250	0.612	0.0106
Carborundum	0.0258	2.45	0.228	0.559	0.0466
Diamel	0.0075	2.30	0.275	0.633	0.0119

TABLE II
HEAT CAPACITIES AND TIME REQUIRED TO HEAT REFRACTORIES

Type of brick	Thickness (inches)	Heat capacity per degree per unit area. Gm/cal.	Time required to reach 95 % saturation in min.
Fire brick	1½	0.889	10.5
	2	1.186	18.7
	2½	1.482	29.2
	5	2.964	116.8
Carborundum	1½	1.065	1.6
	2	1.420	2.8
	2½	1.775	4.4
	5	3.549	17.6
Magnesite	1½	1.352	5.1
	2	1.803	9.2
	2½	2.254	14.3
	5	4.508	57.2
Periclase	1½	1.547	7.2
	2	2.062	12.8
	2½	2.578	20.0
	5	5.156	80.0
Silica	1½	0.787	7.1
	2	1.049	12.7
	2½	1.311	19.8
	5	2.622	79.2
Alundum	1½	1.166	6.4
	2	1.554	11.4
	2½	1.943	17.8
	5	3.886	71.2
Diamel (Fused Magnesia Spinel)	1½	1.205	5.9
	2	1.607	10.5
	2½	2.008	16.4
	5	4.016	65.6

9. Thermal Properties of Various Refractory Types

Silicon-carbide brick have a very high conductivity and diffusivity, and the time required to reach heat saturation is very much shorter than for any other refractory type. According to the results in Table II or Fig. 3, the indicated period of reversal at 1700°F for a standard brick is only about 4½ minutes. Their heat capacity is limited, however, so that their decided advantage is in permitting rapid cycles of operation wherein a unit volume of gas may be made in considerably less time than where other brick are used. Since they are very costly, they must have a long life and freedom from deterioration for a long period of time, as well as superiority in gas manufacture, in order to warrant their extensive use. Based upon results already obtained in a small way and upon their indicated value, several thousand

silicon-carbide brick have been purchased by the Los Angeles Gas and Electric Corporation and are to be given a thorough trial in a regular generator at this Company's works.

Owing to their very high heat capacity combined with high diffusivity and quite high conductivity, greatly surpassing fire brick, the magnesite type of refractories, with respect to their thermal properties, are most nearly ideal for checker use. They absorb the largest quantities of heat of any of the refractories, and the time required for a standard magnesite brick to reach near-saturation is approximately half of that required by fire brick. Since magnesite brick, under most conditions of use, are subject to the serious defects of excessive cracking and spalling, and to disintegration when in contact with steam, their practical use is in doubt at present. Also, their much greater initial cost over fire brick, especially the fused magnesia brick, is an important item. Since the temperatures in the checker-brick section in general are not excessive and the temperature fluctuations are moderate, generally ranging from 100 to 500° per cycle, it appears as though they may be successfully applied to this use. In order to determine this point, a few representative magnesite brick have been placed in representative locations in a generator and are in use at the present time. No report as to their action is as yet available.

Fused magnesia spinel and fused alumina brick appear to have the required stability, are lower in conductivity and diffusivity than silicon carbide and the magnesite type, but are considerably higher in these properties than fire brick. They are very expensive, but appear attractive because of their stability and excellent thermal properties. The time required for them to reach near-saturation is but slightly over the 15-minute heating cycle now used by a number of the plants in operating their generators, while the time required for a standard 9-inch fire brick is about 29 minutes, nearly double the heating period now used. Because of the longer period of reversal of these brick as compared with silicon carbide, longer operating cycles are indicated, but greater heat storage capacity is obtained by their use as compared with silicon carbide. Several thousand fused magnesia spinel brick have been obtained for use in a generator in order to determine their efficiency in gas manufacture. A few representative fused alumina brick are also being given a trial.

Silica brick have higher conductivity, specific heat, and diffusivity than fire brick, require less time to reach heat saturation, but on account of their low apparent density, have a somewhat lower heat capacity. Owing to the fact that the standard 9-inch brick, according to these figures, require but 20 minutes to reach the desirable period for reversal, as compared with nearly 30 minutes for fire brick, their

use is advantageous, provided they remain intact. Owing to their spalling tendencies and sensitiveness to temperature changes, their use also is in doubt. Particularly is this true for generators in intermittent operation, owing to fluctuations in the demand for gas. By slow initial heating up, and by keeping the temperature cycles above 1000°F, it appears that their use would be practical. As in the other cases, a few representative silica brick have been placed in a generator in order to determine their stability under operating conditions.

Critical observation of Tables I and II and of Figures 3 and 4 shows that all the refractories there given are superior to fire brick in one or more of the thermal or heat-transfer properties. Thus fire brick is the lowest in conductivity, diffusivity, and time required to reach 95% saturation. Only silica brick have a lower density and heat capacity than fire brick, while only silicon-carbide brick have a lower specific heat.

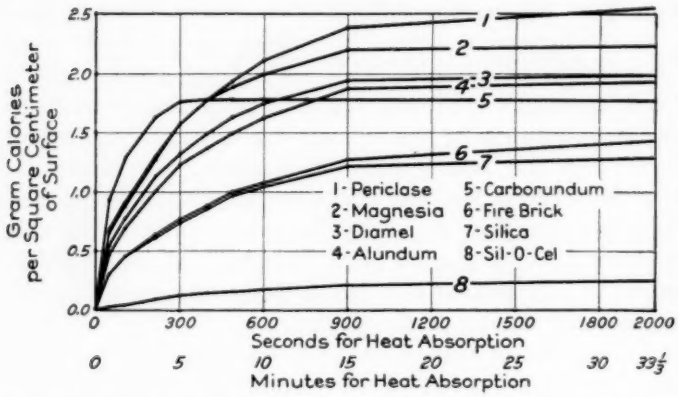

FIG. 4.—Heat absorbed by various refractories 2½ inches thick. Average temperature 1700°.

The extensive use of these refractories is problematical at the present time owing either to their very greatly increased cost or to some marked inherent physical weakness. It therefore is necessary to study the other factors involved in generator checker construction, such as the heat-transfer coefficient between gas and brick, thickness of checker brick used, spacing between checkers, and the proper height of checkers in a generator of given size.

10. Heat-Transfer Coefficient of Gas to Brick

The coefficient of heat transfer, closely related to conductivity, but independent of the kind of refractory used, varies considerably in value, and it determines the rate of heat transfer from the gases to the brick surface. It is dependent upon the temperature of the gases, their density and velocity, size and shape of checker flues. The larger the coefficient the greater is the transfer of heat from the gases to the brick and vice versa. The heat-transfer coefficient in

general grows with the velocity of flow of the products of combustion, so that proper checker spacing is of importance. The value of the coefficient is rather low in generators of average size and average checker spacings, approximations giving a value in the neighborhood of 2.0. It is a difficult constant to determine accurately, but approximate values can be calculated and are of value in determining the necessary amount of heating surface required.

11. Influence of Checker-Brick Height, Thickness, and Flue Spacing

The proper ratio of height of checker brick to heating surface, which permits the greatest increase in heat exchange between the brick and the oil vapors and gases, is not accurately known. Greater ease in uniformity of temperature control from top to bottom checkers is obtained by decreased checker heights. Increased checker heights, especially with close checker spacings, also tend to cut down the velocity of the gases passing by, so that the heat-transfer coefficient of gas to brick is then decreased. Following this line of reasoning, low wide generators appear preferable to the longer narrow ones, but exact limits have not been determined.

The size of checker brick and the spacings between them, determining the size of the checker flues, have an influence on their efficiency. The relative size of brick and checker spacing must be governed by the fact that the arrangement must be such as to offer a maximum area for absorption of heat and a minimum retardation to gas flow, combined with structural strength and durability.

In a given generator with constant checker openings, increased brick thickness increases the cubic feet of brick work in the checkers and weight of brick used. There is a decrease in the space occupied by air or gas, the number of brick used, the number of checker openings, area of these openings, and the heating surface of the checker brick. The ratio of heating surface to cubical contents of brick work is thus lowered by increased brick thickness.

From Table II or Fig. 3, the advantages of using thin fire brick in preference to the thick brick is readily seen, when the heat period of the oil-gas-process cycle is from 10 to 15 minutes. Since the time required for various thicknesses of brick to absorb a given proportion of its maximum heat varies as the square of the brick thickness, brick of relatively low conductivity and diffusivity such as fire brick should be thin for short cycles of heating and cooling. Brick of high conductivity and diffusivity, such as Carborundum, can be used to advantage in the thicker sizes. The use of fire brick thinner than the standard 2½-inch is therefore warranted as long as the stability and structural strength of the checker work is not impaired, so that even

the use of a 2-inch brick is advantageous. Less time is required for heat saturation and there is less lag between the outside skin surface and the interior of the brick with rapid temperature fluctuations and quick cycles. The center of thin brick is therefore more perfectly utilized, although the total heat capacity is lower for the thinner brick.

Theoretically the checker openings should be as small as is consistent with proper gas flow and freedom from danger of excessive carbonization. In a given generator with constant thickness of brick, increased size of checker openings increases the space occupied by air or gas, the area of checker openings, and the ratio of heating surface to cubical contents of brick work. There is a decrease in cubic feet of brick work, number of brick used, number of checker openings, heating surface of checker brick, and weight of brick work in the checkers. The flue spaces must be kept large enough, however, to safeguard against the retardation of gas flow by friction, so that the proper velocity may be maintained.

12. Gas Manufacture By-Products

These are some of the main factors that have to be considered in the use of checker brick in their relation to gas manufacture. The chief undesirable by-products in gas manufacture are carbon, naphthalene, and tar. Large quantities of carbon or lampblack especially are formed. It appears likely that refractories of increased thermal conductivity, especially the crystalline types, will tend to reduce the amount of carbon formed or remaining in the checkers, owing to their ability to rapidly absorb and give up heat. There have been indications that less carbon is formed by the use of Carborundum brick already tried out. The reduction in the amount of the low temperature by-products formed is likely on account of the greatly increased heat capacity of such refractories.

Although the considerations enumerated with regard to the heat-transfer properties of various refractories in their influence upon the conversion of oil to gas in this industry are still in the experimental stage and largely theoretical, they are given in this paper to show the trend of research in refractories by the oil-gas industry on the Pacific Coast. The actual application of the refractories other than fire brick in the industry involves so many variables and so many probable changes in generator operations that a large amount of research is necessary to determine the proper refractories to use as checker brick on the lowest cost-plus-service basis. The changes in generator operation dare not be of such a nature as to alter materially the B.t.u. value, specific gravity, chemical analysis, etc., of the gas made, so that this also must be considered in any checker brick research work.

The oil-gas industry on the Pacific Coast, in coöperation with the California Gas Research Council, is prepared to go to considerable lengths, however, in order to determine the efficiency of various refractories for gas manufacture. If the refractories of superior thermal properties are not practical to use, either on account of excessive cost or inability to withstand operating conditions, a fireclay brick approaching these properties as nearly as possible is the choice. This appears to be as dense a brick of requisite refractoriness as is consistent with freedom from spalling, cracking, and the like, because of its greater conductivity and heat capacity as compared with the softer, more porous fire brick. Also the use of as thin a brick as is consistent with structural strength and durability of the checker work is indicated, since heat saturation is then reached much more quickly.

The confusion existing at the present time as to the thermal conductivities and specific heats at the higher temperatures of the various types of refractories, as well as the total lack of data in many cases, makes it difficult to determine with a sufficient degree of accuracy needed heat-transfer data by which predictions can be made as to their probable use in the regenerative types of processes. Although difficult, the need for systematized work along these lines is evident. The choice of these constants has a material influence on the values obtained in various heat calculations, so that this appears to be a fruitful field for continued investigations on refractories and one worthy of consideration by the Refractories Division of this SOCIETY. The subject is so large that close coöperation between the various interested consumers and manufacturers of refractories would undoubtedly offer the best ultimate solution.

LOS ANGELES GAS AND ELECTRIC CORPORATION
LOS ANGELES, CALIF.

CORRECTIONS

In the paper by A. E. R. Westman and W. W. Pfeiffer, "A Comparison of the Uniformity of Strength and Texture of Fire Brick Made by Different Manufacturing Processes," *Jour. Amer. Ceram. Soc.*, 9 [9], 626–32 (1926), the arrows in Tables III and IV, pp. 630–31, are pointing in the wrong direction. They should point downward in both cases. On page 627, line 37, the word "heat" should be "head"; the phrase should read, "a pressure drop of 1 cm. water head (4°C)."

Heavy Clay Product Manufacturers Annual Meeting

February 8-12

Canadian National Clay Products Association, Toronto, Ontario

February 14-19

AMERICAN CERAMIC SOCIETY
Book-Cadillac Hotel, Detroit, Mich.

February 21-26

Common Brick Manufacturers Association, Sherman Hotel, Chicago, Ill.

These meetings were thus purposefully scheduled that those desiring to attend may route their trip with the least time and money expenditure

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CERAMIC ABSTRACTS

Compiled by

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Ross C. Purdy, *Editor*

Emily C. VanSchoick, *Assistant Editor*

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Art

Decoration of pottery ware by a photographic process. A. SCHODL. *Keram. Rund.*, **33**, 751 (1925).—A short description is given of the method of preparing lithophanes from photographic negatives or positives. (*Trans. Ceram. Soc.* [Eng.])

The growth of crystals in glazes. A. BRASS. *Spreschsaal*, **58**, 591 (1925).—In a glaze made by melting $Na_2B_4O_7$, $10H_2O$, K_2CO_3, $CaCO_3$, ZNO, NiO, TiO_2, SiO_2, $H_4Al_2Si_2O_9$, devitrification due to supersaturation was brought about by varying the ZnO, SiO_2, and NiO. Not only did dendritic, rod-like, and fan-like crystals form on the surface, but magnificent suspended crystals more than 1 cm. long were formed, especially where the glaze was thick. In a suitable theory of crystallization, it was necessary to distinguish between the formation of crystal nuclei and their growth. Aventurine glazes were examples of the formation of many nuclei each of which remained small. For the formation of the large crystals mentioned above it was necessary that the germ or nucleus number (the number of crystal nuclei formed in unit volume in unit time) should be small. By the introduction into glazes of various substances, mixed crystals could be formed which gave all colors according to choice. The most important elements were:

1	2	3	4	5	6	7	8	9	10	11
Cl	S	As	K	Ca	Al	Cu	Pt	C	Ta	Mo
Br	Se	Sb	Na	Ba	Fe	Ag	Ir	Si	Nb	W
I	Te	Bi	Cs	Sr	Mn	—	Pd	Ti		Cr
F		—	Rb	Pb	Cr	Au	Rh	Zr		
		P	Li	Fe	—		Os	Th		
		Vd	Te	Zn	Ce		Ru	Sn		
			Ag	Mn	U		—	—		

1	2	3	4	5	6	7	8	9	10	11
				Mg	—		Au	Fe		
				—			Fe	Tl		
				Ni			Ni			
				Co			Sn			
				Cu			Te			

(*Jour. Soc. Glass Tech. Abs.*)

PATENTS

Modeling clay. EARL E. SNOOK. U. S. 16,435, Oct. 5, 1926. A plastic composition adapted to form a modeling clay comprising approximately 8 oz. of gelatine glue, 11½ oz. of water, 8 oz. of boiled linseed oil, 1 lb. of "titanox," 6 lbs. 1 oz. of bolted whiting, 3 oz. of chrome yellow, and ½ oz. of methyl salicylate.

Decorating pottery. H. FORD AND J. KITTRIDGE. Eng. Pat., 245,209 Oct. 4, 1924. Oily coloring matter is sprayed on water in a trough, and the glazed or unglazed ware is dipped in it so that it takes up the color. Portions of the ware may be coated with clay to prevent the color from adhering. Marbled, grained, fluted, veined, inlaid, and mottled effects may be produced. (*Trans. Ceram. Soc.* [Eng.])

Cement, Lime, and Plaster

Mathers patents process for making any dolomitic lime plastic. ANON. *Rock Products*, **29** [15], 47–48 (1926).—Calcining stone with sodium chloride claimed to result in hydrates equal to best finishing hydrates. F. P. H.

Some modern types of European gas-fired lime kilns. ALFRED B. SEARLE. *Rock Products*, **29** [17], 48–52 (1926).—Characteristics of the usual types of gas-fired kilns of Europe. F. P. H.

Formulas for proportioning raw materials in cement manufacture. RICHARD K. MEADE. *Rock Products*, **29** [17], 61 (1926). F. P. H.

Cement industry and the calcium aluminates. HENRY LAFUMA. *Rock Products*, **29** [19], 60–63 (1926).—A study of the effects of various combinations of calcium aluminates and calcium salts on the properties of cements. F. P. H.

German method of proportioning raw cement materials. H. NITZSCHE. *Rock Products*, **29** [19], 70–71 (1926). F. P. H.

Effect of calcium chloride on cement. C. E. PLATZMAN. *Rock Products*, **29** [3], 78–81 (1926). F. P. H.

Some advances in gypsum technology. J. M. PORTER. *Chem. Met. Eng.*, **33**, 549–50 (1926).—The principal improvement in the manufacture of gypsum, is in the calcination of the rock. This is now done in rotary calciners similar to cement kilns, taking a 3 in. feed. Mechanical handling appliances have been largely substituted for the old handling methods. M. E. M.

Cement. R. W. LESLEY. *Mineral Ind.*, **33**, 104–18 (1924).—Production of Portland cement in the U. S. for the year 1924 totaled 148,859,000 bbls. the largest output in history. A broad and scientific investigation was undertaken by the Bureau of Standards, the Structural Materials Laboratory, and Lewis Institute, Chicago, Ill. A patent was issued to Edwin C. Eckel on a process for the manufacturing of Titan cement as a by-product of the recovery of iron from titaniferous ore. One third of the plants in the U. S. have installed waste heat boilers. Statistics are given for the production of Portland cement and the development of the industry in other countries. T. N. McV.

High sulphur content in Portland cement. F. C. LEA. *Canadian Eng.*, **51**, 133–34 (1926).—The sulphur limit in the British Standard Specification is 2.75% as SO_3. Manufacturers of cement add gypsum, the amount added depending on the season of

the year and the setting time required. The author finds that high gypsum reduces the strength of cement. At the end of one month, concretes with cement containing over 6% SO_3 were cracked, and with 6½% were badly cracked. With lower per cent than 6, no obvious disintegration was observable during 11 months. The Le Chatelier non-expansion test for soundness fails to detect unsoundness due to gypsum. When steel is embedded in cement, gypsum has no effect on it. H. H. S.

Magnesium oxychloride cements. ANON. *Quarry*, **30**, 317 (1925).—A non-corrosive cement, having all the properties of oxychloride cements, has been produced by substituting ferrous chloride for magnesium chloride in the mixing.
(*Trans. Ceram. Soc.* [Eng.])

Ciment fondu. ANON. *Chem. Trade Jour.*, **78**, 95 (1926).—An account is given of the origin and development of ciment fondu, together with a description of the new works at Thurrock, Essex. (*Trans. Ceram. Soc.* [Eng.])

The injurious effect of high temperatures upon Portland cement. H. KAYSER. *Zement*, **14**, 634–35 (1925).—To determine the truth of a published statement that the simple ignition of Portland cement would greatly increase its strength, improve its setting properties and appearance, K. heated 3 widely differing kinds of cement to 900° for an hour. It was found that the strength was decreased in all cases, as much as 77% of the original strength being lost in 1 case. No advantage was found in the other properties tested. (*C. A.*)

PATENTS

Manufacture of aluminous cements, colored or white. U. B. VOISIN. Eng. Pat., 248,282, Oct. 14, 1925. The aluminous cement mass, very finely ground and very intimately mixed, is roasted for a long period (6 to 8 hrs.) at a temperature well below the softening point (1000–1100°). A white cement is produced by the use of white bauxite and pure lime. (*Trans. Ceram. Soc.* [Eng.])

Aluminous cements. ANON. Eng. Pat., 250,246, Mar. 31, 1926. The raw materials, very finely ground, are heated to 1000–1100°. It is unnecessary to use pure materials. The composition of the cement produced may vary within wide limits: silica, 0–5%, alumina, 40–55%, iron oxide, 10–25%, lime, 20–40%.
(*Trans. Ceram. Soc.* [Eng.])

Enamels

A trip through a British enamel plant. ANON. *Ceram. Ind.*, **6** [5], 479–82 (1926).—A description of the method of manufacturing enamel ware as practiced in England. F. P. H.

It is all in the mixing of enamels. ANON. *Ceram. Ind.*, **7** [4], 366–67 (1926).—In dealing with cast-iron enamels great care should be taken to mix thoroughly and smelt slowly to prevent defects from appearing on the ware. The lower the furnace temperature is when the raw batch is introduced the longer will be the smelting time. It is better to smelt slow than fast because in firing slow you will have a more homogeneous mass and it will have more life to it; that is, it will be, providing other things are equal, a glossier, stronger, and tougher enamel. F. P. H.

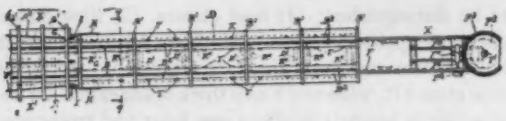
Dipping and slushing enamel ware. F. M. BURT. *Ceram. Ind.*, **7** [4], 370–72 (1926).—Discussion of causes of hollow ware defects. Ground coat and cover coat dip troubles are treated. Methods of handling sprayed and dipped ware are discussed. F. P. H.

Fluorspar in enamels. L. VIELHABER. *Emaillew. Ind.*, **83** (1926).—Fluorspar is a cheap opacifying medium, which has no serious effect upon the expansion, elasticity, and strength of enamels. It has been used in many cases to increase the elasticity in

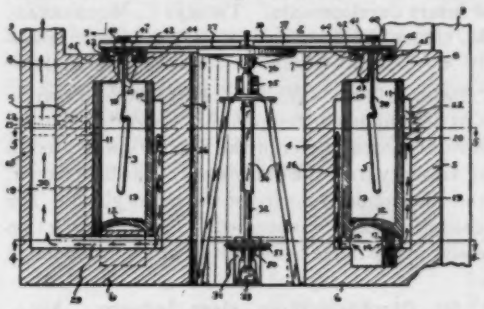
order to prevent chipping of the enamel from corners, etc. Its effect upon the elasticity being great and upon expansion comparatively slight, it is suitable raw material for enamels for cooking utensils. (*Trans. Ceram. Soc.* [Eng.])

PATENTS

Furnace for enameling metal ware. H. C. Beasley and Robert MacDougall. U. S. 1,603,014, Oct. 12, 1926.



A furnace comprising a central heating chamber, a pair of preheating chambers located one at either end of the heating chamber, and a pair of drying chambers communicating each with one of the preheating chambers, the central chamber being formed into 2 separate chambers, the preheating and drying chambers being formed each in one chamber.



Process of enameling. Edgar H. Weil. U. S. 1,603,368, Oct. 19, 1926. The process of vitrifying enamel on a substantially flat article having broad faces, which comprises supporting the article substantially vertically, and subjecting the opposite faces of the article substantially uniformly to radiant heat to thereby substantially uniformly heat the article, and vitrify the enamel thereon.

Manufacture of enameled objects. M. J. Davidsen. Eng. Pat., 248,514, Dec. 24, 1924. A cement, rich in alumina and poor in silica and lime, is mixed with not more than 15% of sand or Portland cement, or both, sufficient water for setting being added. Objects made for the mixture are allowed to harden in air or water and subsequently enameled and fired in the usual way. (*Trans. Ceram. Soc.* [Eng.])

Opacifying media for enamels. L. Kreidl. Eng. Pat., 24,575, Dec. 29, 1925. White oxides of metals, not normally used as opacifiers, are rendered suitable by converting them into a gel form in colloid mills. Known opacifying agents are added to prevent the colloidal substance from dissolving in the enamel mixture. (*Trans. Ceram. Soc.* [Eng.])

Enameling (cadmium and zinc surfaces.) H. C. Pierce and C. H. Humphries. U. S. 1,583,006 May 4, 1926. The surfaces are treated with a solution of an arsenate and enameled in the usual way. (*Trans. Ceram. Soc.* [Eng])

Glass

Producer gas application to glass-melting furnaces. Scott Davidson. *Fuels and Fur.*, **4** [8], 943–44 (1926).—D. describes the procedure followed by his Company in operating a gas producer at a low operating cost. An analysis of the fuel, a typical daily log reading, and a calculation of the cost per ton of glass made are given. A. E. R. W.

Producing glass sand to specifications. H. V. Kelley. *Rock Products*, **29** [8], 72–73 (1926). F. P. H.

Shop talk on glass annealing. L. Springer. *Ceram. Ind.*, **7** [4], 344–45 (1926).—There are two temperatures to consider in annealing glasses: (1) An upper annealing temperature which lessens rapidly the stress in the glass which might cause its fracture

and above which a materially increased diminution of stresses does not occur: (2) A lower annealing temperature, below which a glass will not be submitted to remaining stresses, and at which temperature existing stresses will not disappear in practical length of time. The practical annealing must take place between these two temperatures. The results of an investigation by English and Turner are quoted. According to E. and T. the annealing temperatures depend on the composition of the glass, and 4 types have to be distinguished: (1) lead glasses, (2) lime glasses, (3) boric acid glasses, and (4) chemical apparatus glass. Methods for annealing these 4 types and the annealing of hollow glass and sheet glass are discussed. According to Ford's process thin cast window glass 3 ft. wide and 8 mm thick is annealed in a leer of about 405 ft. in length (150 ft. of which is heated) in about one hour and twenty minutes from 600°C down to 30°C.
F. P. H.

Glass bottle machinery growth and future developments. THOMAS C. MOORSHEAD. *Ceram. Ind.*, **6** [5], 468–78 (1926).—M. traces the development of the modern glass-blowing machine. F. P. H.

Viscosity of commercial glasses. ANON. *Ceram. Ind.*, **6** [5], 478 (1926).—Progress of work done at Bureau of Standards to determine the temperature-viscosity relations of glasses of different composition. A rotary viscosimeter of the Searle type is used in this work. An equation for calculating viscosity from the dimensions of the instrument, the weight rotating the stirring rod, and the angular velocity of the rod is given. The effect of variations in friction due to change in speed was studied. The end correction was found to vary with increasing viscosity in the range of viscosities which are found in glass. F. P. H.

Machine competition too much for Czechoslovakian glass industry. ANON. *Amer. Glass Rev.*, **46** [1], 14 (1926); *Nat. Glass Budget*, **42** [22], 19 (1926), (reprinted from *United States Daily.*).—A discussion of the prevalent depression in all branches of the glass industry of Czechoslovakia due to competition of American machine-made products
E. J. V.

Rejuvenation of Diamond Glass-ware Co's. plant. J. M. HAMMER. *Amer. Glass Rev.*, **46** [2], 17 (1926).—A description of new installations in the factory at Indiana, Pa., to modernize production methods. E. J. V.

The manufacture and use of cullet. D. J. MCSWINEY. *Glass Ind.*, **7** [3], 66–67 (1926).—The sources of cullet, such as off-ware, the glass run off in clearing a spout or trough, and that used to bring molds to the forming temperature, are enumerated and discussed. The only too apparent lack of knowledge regarding the actual action of cullet in glass and its effect on the nature of glass is brought out. Some theories on the effect of cullet are mentioned and discussed, as are methods of keeping the cullet pile small. The main solution to the problem of reducing the amount of cullet due to off-ware is given as lying in a careful record of off-ware under all different conditions at each step in manufacturing processes and variation of operating or glass conditions to eliminate causes of off-ware formation. E. J. V.

A new method of producing colored glass. W. C. TAYLOR. *Glass Ind.*, **7** [4], 90–91 (1926); see also *Ceram. Abs.*, **5** [4], 121 (1926).—The addition of certain alkali metal halides, or the halogen salts of other elements to a glass batch containing coloring oxides or salts will effect modifications on the color produced usually in the resultant glass. Many different colors may be obtained by varying the ratio of the halide salt to the metallic oxide or salt used to produce the color, or by varying the ratio existing between the alkali salts, silica, and boric oxide contents of a borosilicate glass. High boron glasses show most noticeable effects. The effect of halogen salts is the reverse of that of boric oxide. The following batch formulas illustrate the invention:

	Silica SiO_2	Boric Oxide B_2O_3	Alkali as potash K_2O	Alumina Al_2O_3	Cobalt oxide Co_2O_3	Nickel oxide NiO	Alkali as soda Na_2O
1	55	80			.1		5
2	47	39	11	3	.1		
3	47	39	11	3		.1	
4	47	39	11	3	.2		
5	66	32	2		.2		
6	55	31	14		.1		
7	55	31	14			.1	
8	68	24	8		.2		
9	76	19	5		.2		
10	70	12	18		.1		
11	65	23	7	5	.3		
12	65	23	7	5		.1	

Soda (Na_2O) and sodium chloride may be substituted for potash (K_2O) and potassium chloride in molecular percentages respectively without affecting the described colors. By adding 97 parts of batches of the above formulas to 3 parts of potassium chloride and melting, glasses will be produced having the following colors in plates 6 mm thick, when viewed by transparent light from a tungsten filament lamp, as contrasted with the colors of such glass without the chloride.

	Color with KCl added	Color without KCl
1	Green	Red
2	"	"
3	Indigo	Lemon yellow
4	Blue green	Red
5	Blue	Red inclined to purple
6	"	Red purple
7	Violet	Yellow
8	Blue	Red purple
9	Blue purple	" "
10	Blue	Blue purple
11	"	Red purple
12	Amber	Amber

Bureau of Standards reviews year's work. GEORGE K. BURGESS. *Glass Ind.*, **7** [10], 45–46 (1926; see also *Ceram. Abs.*, **5** [11], 349 (1926). E. J. V.

The water-cooling of glass tanks. ANON. *Glass Ind.*, **7** [10], 231–33 (1926).—Various devices and methods of water-cooling glass tanks are discussed at length, advantages and disadvantages of each being pointed out. Generally speaking, water-cooling of walls of a tank is resorted to as a last resort to prolong its life a few weeks. While it is a consensus of opinion that water-cooling of the bridge wall is a good thing, few men who have tried the different ways of water-cooling will recommend it as standard practice. E. J. V.

Fifty years of glass making. ALEXANDER SILVERMAN. *Glass Ind.*, **7** [10], 242–43 (1926); *Nat. Glass Budget*, **42** [22], 3 (1926); *Amer. Glass Rev.*, **45** [52], 17 (1926); *Pottery Gaz.*, **51** [592], 1552–54 (1926); (reprinted from *Ind. Eng. Chem.*, **18** [9], 896–99 (1926); see also *Ceram. Abs.*, **5** [11], 347 (1926). E. J. V.

The use of temperature gradients in the fabrication of blown glass ware. ROY E. SWAIN. *Glass Ind.*, **7** [10], 233–35 (1926).—One of the most important aids a glass maker uses in blowing his ware is that of temperature gradients. S. takes up the evolution of articles in each of a few well-known types of glass working to explain how and why the glass worker uses temperature gradients. E. J. V.

Zinc oxide and "seeds" in borosilicate crown glass. ANON. *Glass Ind.*, **7** [10], 238 (1926); (reprinted from *Tech. News Bull.*).—In an attempt to produce borosilicate crown glass with an index of refraction of approximately 1.517, the zinc oxide was eliminated but this produced "seedy" glass unfit for use. Good glass with a slightly higher index was obtained with 2% zinc oxide. E. J. V.

The story of engraved glass. GARDNER TEALL. *Glass Ind.*, **7** [10], 239–41 (1926); (reprinted from *House and Garden*).—An abstract of a short historical sketch on engraved glass. E J. V.

Glass making at Ford plants. ANON. *Nat. Glass Budget*, **42** [22], 7 (1926); (reprinted from *Chicago Journal*).—A description of glass used by Ford, methods of making it and data on amounts produced in his plants and used in his cars. E. J. V.

"Ancient glass" buyer fooled. M. L. BLUMENTHAL. *Nat. Glass Budget*, **42** [23], 9 (1926); (reprinted from *Sat. Eve. Post*).—The early history of American glass making is given and collectors are warned that, as little early American glass was marked, any old glass which is not marked is denominated as early American glass. E. J. V.

Glass industry in Italy. ADAM BEAUMONT. *Nat. Glass Budget*, **42** [23], 17 (1926).—With the exception of that located in Venice, the glass industry of Naples is the most important in Italy. Common glassware, the chief product, is distributed largely in Italy. E. J. V.

Flat glass conditions in Belgium. W. C. BURDETT. *Nat. Glass Budget*, **42** [23], 18 (1926); *Amer. Glass Rev.*, **46** [1], 16 (1926); (reprinted from *Commerce Reports*).—Conditions of the plate glass industry continue satisfactory. It is expected sheet drawn plate will be produced soon by a process similar to that devised by the Ford Motor Co E. J. V.

Chance's Crookes' glass. ANON. *N at. Glass Budget*, **42** [23], 19 (1926).—A note on a booklet describing Crookes' glass published by Chance Brothers and Co., Ltd., of Birmingham, England. E. J. V.

Plate glass booklet. ANON. *Nat. Glass Budget*, **42** [23], 21 (1926).—A note regarding the "Age of Plate Glass," issued by the Plate Glass Manufacturers of America. E. J. V.

Modern glass-metal recipes. O. LECHER. *Pottery Gaz.*, **51** [592], 1564–65 (1926); (translated from *Metallbörse*).—Methods of making lead, baryta, sulphate, and plate glasses are described and their differences explained. Formulas found satisfactory in German and Bohemian practice are as follows:

LEAD CRYSTAL GLASS

	1 %	2 %	3 %	4 %	5 %	6 %	7 %
SiO_2	53.40	51.15	48.04	65.99	65.50	62.50	68.50
Al_2O_3	1.11	0.89	0.79	1.23	0.99	1.46	1.59
Fe_2O_3	0.04	0.03	0.06	0.07	0.13	0.11	0.10
CaO	——	——	——	——	8.33	8.50	8.93
PbO	32.11	38.20	39.66	15.15	15.58	16.03	4.73
Na_2O	——	1.74	1.11	6.67	8.35	1.11	12.67
K_2O	13.36	8.04	10.45	10.98	1.11	10.40	3.41
Proportions of Charge by Weight							
Sand	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Marble	——	——	——	——	23.00	24.00	23.00
Red lead	61.11	75.5	83.5	24.00	24.5	27.00	7.00
Soda (90%)	——	6.00	4.00	18.00	23.00	3.00	33.00
Potash (90%)	32.00	20.00	28.00	20.00	——	23.00	5.00
Niter	7.00	6.00	7.00	7.00	3.00	3.00	2.00

BARYTA GLASSES

	Pure Baryta Glass		Baryta-Lime Glass	
	1 %	2 %	3 %	4 %
SiO_2	58.06	69.88	65.94	72.85
Al_2O_3	1.45	1.12	1.67	1.98
Fe_2O_3	0.06	1.10	0.09	0.11
CaO	——	——	6.44	8.58
BaO	25.03	12.15	14.63	4.11
Na_2O	15.51	14.20	9.58	9.60
K_2O	——	2.50	1.68	2.85
Proportions of Charge				
Sand	100.00	100.00	100.00	100.00
Soda	47.5	36.5	26.00	23.5
Potash	——	5.5	4.5	6.00
Ground marble	——	——	17.00	21.00
Barium carbonate	53.5	21.5	27.5	7.00

	Baryta-Lead Glass		Baryta-Lead-Lime Glass	
	5 %	6 %	7 %	8 %
SiO_2	53.40	65.11	60.50	70.88
Al_2O_3	1.06	1.01	1.50	1.21
Fe_2O_3	0.05	0.07	0.10	0.12
CaO	——	——	4.62	4.30
BaO	10.10	6.86	6.44	1.48
PbO	22.11	10.03	16.75	10.66
Na_2O	——	12.10	1.46	8.94
K_2O	13.36	4.87	8.62	2.44
Proportions of Charge				
Sand	100.00	100.00	100.00	100.00
Soda (90%)	——	33.5	4.5	23.00
Potash (90%)	35.00	10.00	18.00	2.00
Marble	——	——	13.5	11.00
Barium carbonate	23.00	13.00	13.00	2.7
Red lead	41.5	15.5	28.00	15.00
Niter	3.00	2.00	4.00	4.00

SULPHATE GLASS
Proportions of charge

	Bottle Glass	Plate Glass
Pure Sand	100.0	100.0
Glauber's salt (98%)	39.0	42.0
Marble	28.0	29.0
Coal or anthracite	2.5	2.6

E. J. V.

The annealing of glass. ANON. *Pottery Gaz.*, **51** [592], 1573(1926).—See also *Ceram. Abs.* **5** [10], 300(1926). E. J. V.

The Belgian glass industry. ANON. *Pottery Gaz.*, **51** [592], 1575(1926).—A note on the history of the Cristalleries de Val St. Lambert which celebrated their centennial. See also *Ceram. Abs.* **5** [11], 349(1926). E. J. V.

Russian glass industry. ANON. *Pottery Gaz.*, **51** [592], 1575(1926).—Notes on the mechanizing of a plant at Odessa and the construction of several new plants at various other places. E. J. V.

Glass industry in Germany. ANON. *Pottery Gaz.*, **51** [592], 1576 (1926).—Due to the general bad state of business there has been a considerable expansion of the crystal glass trade since many firms not specializing in the production thereof have taken up the sale of these goods. E. J. V.

Optical glass manufacture. ANON. *Nature*, **118**, 340–41 (1926).—Large disks of optical glass are required only rarely and their manufacture is a delicate operation requiring a special plant. The optical works of Howard Grubb, Parsons and Co., set up in 1926 at Newcastle (England) solves this problem. The shop possesses a 5T. electric traveling crane; one end of the bay is fitted up as a machine and fitting shop, and the other is used for the erection of instruments. Means of testing large instruments in course of construction by actual observation of stars is thus provided. At the present time the H. Grubb, Parsons Co. is engaged in constructing a refracting telescope with an object glass of 41 inches diameter. When completed this telescope, which is intended for the Simeis Observatory in southern Russia, will have a slightly larger aperture than that of the Yerkes Observatory. The focal length will not be so long, as this instrument is designed for photographic rather than visual work. This article is illustrated. O. P. R. O.

Alumina as a glass oxide. R. SCHNEIDER. *Glashütte*, **56**, 403 (1926).—Consideration is given to the use of aluminum hydroxide (Al_2O_3, $3H_2O$) in the making of glass. Its properties are compared with those of the more common alumina-containing ingredients, feldspar, pegmatite, kaolin, etc. (*Trans. Ceram. Soc.* [Eng.])

The mechanical, thermal, and optical properties of fused silica. E. THOMSON. *Quarry*, **31**, 17 (1926).—A general review. Probably future uses, are, in the manufacture of high-tension insulators, and of astronomical mirrors. (*Trans. Ceram. Soc.* [Eng.])

Dilatometric and thermal study of soda-silica glasses. M. O. SAMSOEN. *Compt. rend.*, **183**, 285–86 (1926).—Measurements carried out on soda-silica glasses by the method of Chevenard show a maximum coefficient of dilatation at 15° for a silica content of 56%. A maximum transformation temperature, between two minima, is observed corresponding to the composition $2SiO_2$, Na_2O, which is analogous to alloys and salt mixtures forming eutectics. This and SiO_2, Na_2O are the only definite compounds existing in the silica-soda system in the vitreous state, the minima corresponding to a mixture of these two compounds, containing about 56% SiO_2, and a mixture of silica and the compound $2SiO_2$, Na_2O, containing about 73% SiO_2. Glasses of composition falling on the branch of the curve extending from SiO_2, Na_2O to the first minimum are very easily devitrified. (*Brit. Chem. Abs.*)

The significance of the lead-glass laws for the crystal and optical glass industry. E. ZSCHIMMER. *Sprechsaal*, **58**, 576 (1925); *Jour. Soc. Glass Tech.* **9**, 265 Abs.—The alkali content of Pb glasses should be calculated from the equation: $\%R_2O = (76 - PbO\%)$ 0.27, whereas G. Keppeler suggests $\%R_2O = (79.4 - PbO\%)$ 0.26. Good firing conditions are essential but a small amount of B_2O_3 and Al_2O_3 permit a smaller % of R_2O. A PbO content between 30 and 40% causes "sweating," and "specking" if between 50 and 60%, due to separation of Pb. (*C. A.*)

Physico-chemical problems of glass technic and ceramics. G. KEPPELER. *Z. Elektrochem.*, **32**, 378–82 (1926).—A review, stating such problems as better knowledge of the constitution of glass molecular complexes, the nature of silicate ionization and its effect upon glass at high temperatures, the composition-solubility-conductivity relationships, and the "heat history" of ceramic bodies. (*C. A.*)

Studies by the Taylor system of the technic of analysis of raw materials for glass. DOROTHEA JAPHE. *Sprechsaal*, **58**, 807–18 (1925); *Chem. Zentr.*, **1926**, I, 1609.—Known methods for determining soda are compared with respect to their precision and the time required. (*C. A.*)

Quartz glass. New progress in the industry. P. GILARD. *Rev. universelle mines*, 10 [7], 27–38 (1926).—An illustrated description of new types of equipment. (*C. A.*)

Studies on penetrability of various rays through glasses. I. Ultra-violet ray penetration through alkali-lime glasses, and the method of manufacture of glass transparent to ultra-violet rays. S. SUGIE. *Report Osaka Ind. Research Lab.* (Japan), 5 [11], 1–26 (1924).—Fifty-one different soda-lime glasses were prepared and their absorption of ultra-violet rays was studied. The range of composition of the glasses was 0.7–1.6 Na_2O, 0.9–1.5 CaO, 6 SiO_2. The results are given in 21 tables and 21 spectrophotographs. A few glasses, in which part or all of the Na_2O was substituted by K_2O, were also used. There seems to be no systematic relation between absorption of ultra-violet rays and the composition of the glass. The glass most transparent to the ultra-violet rays has the composition 1.0 Na_2O, 1.4 CaO, 6 SiO_2; this transmits wavelengths as small as 237$\mu\mu$ (thickness 1.5 mm) and the least transparent one (1.0 Na_2O, 1.5 CaO, 6 SiO_2) transmits down to 279$\mu\mu$ (thickness 1.5 mm). Although the penetrability to ultra-violet rays is inversely proportional to the thickness of the glass, the least transparent glass cannot be made equal in penetrability to the most transparent by decreasing the thickness. Substitution of Na by K does not alter the transmitting quality of the glass. The results of the experiments on the effects of other chemicals show that P_2O_5 shows no effect; Sb_2O_3, TiO_2 and Fe_2O_3 (also MgO and Al_2O_3) decrease the penetration. **II. Ultra-violet ray penetration through alkali-barium glass and alkali-zinc glass.** *Ibid*, [15], 1–19.—The experiments conducted with 48 kinds of Na_2O-BaO glass (0.6–1.3 Na_2O, 0.6–2.0 BaO, 6SiO_2) show that with a thickness of 1.5 mm, the shortest wave which penetrated was 270$\mu\mu$. In general, an increase of BaO tends to decrease penetrability of the ray. With 24 Na_2O-ZnO glasses (0.8–1.4 Na_2O, 0.6–1.6 ZnO, 6 SiO_2), under a similar condition, 260$\mu\mu$ was the shortest wave which went through. In general, an increase of Zn seems to increase transmission of the ray. In Na_2O-BaO glass, substitution of Na by K produces no effect while in Na_2OZnO glass, K seems to decrease the transmitting power of the ray. **III. Glasses non-transparent to visible, but transparent to ultra-violet rays.** *Ibid*, 6 [4], 1–26.—The effects of Ni and Ca in alk.-lime, alk.-Ba, alk.-Zn and other glasses upon transparency to visible and ultra-violet rays were investigated. Ni makes glass more transparent to ultra-violet rays, up to a certain point. With 0.8–10% NiO present, the minimum wave lengths transmissible are 290–300$\mu\mu$. Transparency of Ni glass to ultra-violet ray is not affected by the kind of alkali present in the glass, but the transparency to visible rays is affected, according to whether K or Na is used. Thus in potash glass containing Ni, the shortest transmitted visible ray has a greater wave length than that in soda glass containing exactly the same amount of Ni. An addition of Cu to Ni glass to absorb the red rays absorbs ultra-violet rays at the same time. Presence of 1% Cu is permissible. Co behaves like Ni. Thus for manufacture of black glass transparent to ultra-violet rays, Co can be substituted for Ni, although the use of both in the same glass will diminish its transparency to the ultra-violet rays. (*C. A.*)

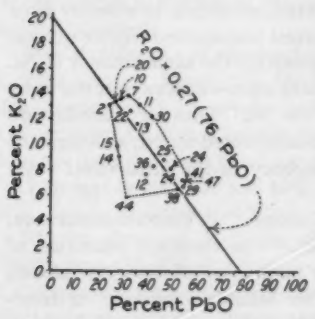
Testing chemical (and optical) glass ware. W. TEPOHL. *Z. Instrumentenkunde*, 45, 389–92 (1925); *Jour. Soc. Glass Tech.*, 9, 268 (Abs.).—The chemical resistance of apparatus glass may be satisfactorily determined by the methods of Mylius (*Sprechsaal*, 1923, *Glastech. Ber.*, 1, Nos. 2 and 5, *C. A.*, 8, 1000).—The "soluble alkalinity" is determined by heating the samples (test tubes) 3 hrs. at 80° with neutral distilled water, quick cooling and titration with Na iodoeosin and Et_2O. A glass of high quality will yield 20–100$\times 10^{-3}$ mg. Na_2O/sq. dm., softer and poorer glasses 600$\times 10^{-3}$ mg. Na_2O/sq. dm. and more. According to this test Mylius arranges glasses in 5 classes. To determine the resistance against alkalis boil 1–3 hrs. with Na_2CO_3 or NaOH solution, using a reflux, and calculate the loss in weight as decrease per sq. dm. surface. The

durability of optical glass is determined by its *"natural"* and *"weathering alkalinity,"* the first on a fresh surface of fracture and the second on a surface of fracture exposed 7 days at 18° in air saturated with water vapor. The samples are kept 1 minute in a solution of iodoeosin in water saturated Et_2O. The alkali liberated by the hydrolytic decomposition on the glass surface forms a cherry-red salt with iodoeosin, which sticks to the glass. The collected salt is dissolved in a 0.01% Na_2CO_3 solution and determined colorimetrically. Optical glasses are arranged in 5 "weathering classes," class 5 yielding more than 40 mg. iodoeosin salt/sq. m. White spots often appearing on optical glasses are due to an action of acids, which may be tested according to the method of Zschimmer (*Z. Instrumentenkunde* **23**, 55 (1903)) by employing one drop of 0.5% AcOH, containing 0.05% glycerol, which is allowed to act for 24 hrs. After washing and drying the surface is examined. (*C. A.*)

Action of caustic soda upon Jena glass. ENRICO CAROZZI. *Giorn. chim. ind. applicata*, **7**, 129 (1925).—Solutions of 10 *N* and 2.5 *N* NaOH were kept in flasks of Jena glass at ordinary temperatures and under conditions not allowing of any evaporation for a period of 12 yrs. Into the 10 *N* NaOH had passed, per sq. cm. of glass exposed to the solution, 6.87 mg. SiO_2, 0.55 Al_2O_3 and 1.74 ZnO; similarly for the 2.5 *N* solution, 2.90 mg. SiO_2, 0.27 Al_2O_3, 0.73 ZnO. Under similar conditions, but in a period of 6 months, and with, resp., 2.5 *N*, 1 *N* and 0.1 *N* NaOH solutions, the following results, in mg. per sq. cm. of exposed surface, were obtained: SiO_2, 0.74, 0.53, 0.14; Al_2O_3, 0.07, 0.04, 0.013; ZnO, 0.21, 0.13, 0.03. These figures indicate the possible appreciable errors that may arise in analyses where Zn is concerned, from the use of NaOH solutions standing in contact with Jena glass for long periods of time. (*C. A.*)

The roughening of calcium phosphate glass for lighting purposes. E. ZSCHIMMER, K. HESSE, AND L. STOESS. *Sprechsaal*, **58**, 513–17, 529–34 (1925); *Chem. Zentr.*, I, 207 (1926).—The tendency to become rough depends on the separation of relatively coarse Ca phosphate crystals and crystalline skeletons. The origin of these was studied microscopically in various industrial batches. A comparison of temperatures and times of working in the manufacture indicated that the temperature is of paramount influence on the formation of Ca phosphate crystals, whereas the chemical composition is of relatively little significance. (*C. A.*)

The constituents of lead glasses. O. KNAPP. *Sprechsaal*, **58**, 424 (1925); *Jour. Soc. Glass Tech.*, **9**, Abs., 190–91.—Of the rules given for the compn. of Pb glasses, those of G. Keppeler (cf. *Sprechsaal*, **57**, 573) and E. Zschimmer (*i.e.*, $R_2O = 0.27[76 - PbO]$, where R_2O and PbO represent the percentage amounts of these oxides present) were not generally applicable. The figure is due to D. Japhe and shows that the composition is best indicated by a plane figure and not by a line. It is possible for salts of the following silicic acids to occur: H_2SiO_3, $H_2Si_2O_5$, $H_2Si_3O_7$, $H_2Si_4O_9$, together with free silica or free Pb oxide in mutual solution in the glass. Based on this hypothesis, the compositions of a number of Pb glasses have been recalculated in terms of relative molecular percentage in Table I. In most glasses more or less free silica occurs, tending to glass of acidic character, but basic glasses are possible containing free Pb oxide. The "normal" glass is neutral and other neutral glasses can be obtained containing trisilicates in molecular proportions of $0 < :2$ to $2: > 0$. In this restricted case, namely, in absence of free oxides, Keppeler's and Zschimmer's rules are valid. Practical support of the above hypothesis is found in the facts (1) glasses



rich in Pb oxide are yellow in color, indicating solution of free PbO, and (2) values of constitutive properties deviate from those calculated by additive rules from the individual oxides, indicating salt formation. The specific constants for Pb glasses remain to be calculated.

TABLE I

Glass No.	Description	Composition			Salts of acid	Constituents present—Mols. per cent			
		K_2O	PbO	SiO_2		Potash salt	Lead salt	Free SiO_2	Free PbO
1	Hard crystal glass	9.0	30.5	60.5	$H_2Si_4O_9$	31.79	45.36	22.85	——
2	Ordinary crystal	9.5	29.6	60.9		24.88	32.76	42.36	——
3	"Normal" glass (1 : 1 : 6)	13.9	32.8	53.3	$H_2Si_3O_7$	50.00	50.00	——	——
4	French lead glass	13.5	31.3	55.2		40.86	40.00	19.14	——
5	English crystal	13.8	33.7	52.5	$H_2Si_2O_5$	27.22	30.00	42.77	——
6	Springer's lead glass	11.1	35.1	58.8		34.04	51.37	14.59	——
7	Strass	7.9	53.0	38.1		13.34	37.67	48.95	——
8	Optical heavy flint	1.5	71.2	27.3	H_2SiO_3	3.54	70.80	25.66	——
9	Lead silicate S. 208	—	80.0	20.0		——	92.23	——	7.77
10	Silicate flint S. 57	—	82.0	18.0		——	81.53	——	18.47

(*C. A.*)

Glass decolorizers. W. HACKER. *Glashütte*, **56**, 224 (1926).—The following mixture was recommended as a decolorizer: pyrolusite 30, selenium 25, bismuth oxide 20, nickel hydroxide 15, arsenious acid 10. A batch in which metallic antimony was used for decolorizing was: sand 100 kg., soda ash 35 kg. limespar 16 kg., potassium nitrate 3 kg., pyrolusite 165 gm., metallic antimony and arsenic 100 gm., cobalt oxide 0.2 gm.

(*Jour. Soc. Glass Tech. Abs.*)

Glass for condenser lenses. G. JAECKEL. *Glasind.*, **34**, 4 (1926).—Includes a discussion on the constituents of glass which furnish heat-resisting properties. The composition of Resista glass was quoted as: SiO_2 65.6, B_2O_3 17.94, Al_2O_3 2.24, Fe_2O_3 0.10, ZnO 3.25, PbO 0.28, CaO 0.29, Na_2O 6.88, K_2O 0.51, Sb_2O_3 2.91, being very different from that quoted by H. Thiene (see *Ceram. Abs.*, 5 [7], 207 (1926)). A good condenser lens should transmit, not only the heat rays, but also a high proportion of the visible light rays. For this reason, J. preferred the German Ignal glass to Pyrex.

(*Jour. Soc. Glass Tech. Abs.*)

Light-absorbing glasses. E. WEISS. *Glasind.*, **34**, 49 (1926).—Screens for the visible portion of the spectrum might be divided into 2 groups. The first group (green, bluish-green, and blue) were used to make artificial light resemble daylight. The spectrum of sunlight differed from that of diffused daylight, and underwent daily and seasonable variations. Spectra of artificial light also varied according to the type of light source. Hence a screen had to be chosen according to the exact conditions. Glasses of the 2nd group were red to yellow in color and were useful to improve sharpness and range of vision during misty weather and at dusk and dawn. By Rayleigh's rule, red should be the best for these purposes, but the sensitivity of the human eye toward red light was low, and an orange, or, better still, a yellow screen was best in practice. The blue to green group was almost opaque to infra-red radiations. The red to yellowish-green glasses were nearly opaque to ultra-violet rays. Attempts to make glasses that would absorb the intense ultra-violet rays of natural light and also the weaker but shorter ultra-violet rays from artificial light had led to glasses that absorbed practically all the ultra-violet light, but were useless for seeing. Two classes of glasses for absorbing ultra-violet rays were made. One of the Crookes' type had a sharp limit of transparency in the neighborhood of the visible violet light and were colorless. The other class (e. g., Fieuzal, Euphos, Hallauer, Enixanthos, Umbral) absorbed the visible violet and blue in considerable quantities and in the darker varieties the absorption extended to the

yellow and red rays. Thus yellowish-green, brownish-green, or brown glasses were suitable for protecting the eye against bright sources of illumination as met on mountain tops, in the tropics, and on the sea. Although such glasses absorbed infra-red rays better than ordinary colorless glasses, no glass was known that transmitted the visible spectrum but absorbed both the infra-red and the ultra-violet rays. For protecting the eye from high temperature furnaces or when welding, a combination of a blue to green glass with a red to green glass had to be used. Such a combination reduced the intensity of the visible rays and absorbed both the infra-red and the ultra-violet rays. Very unsuitable employment of colored glasses could often be observed, *e.g.*, red glass for artificial illumination of shop windows, causing an increase in the color error compared to daylight, or blue glass automobile anti-glare screens which caused a decrease in color contrasts.

(*Jour. Soc. Glass Tech. Abs.*)

A multi-lens automatic camera (for the study of the devitrification of glass at high temperature). A. J. DALLADAY AND T. P. ANDERSON. *Jour. Sci. Instr.*, **2**, 209 (1920).—D. and A. described an apparatus suitable for automatically taking photomicrographs of the changes in small specimens of glass heated in 5 electric microfurnaces of alundum tube 1 in. long and ½ in. internal diameter. The specimens were supported at the center of the tube by the thermocouple, insuring as correct a reading as possible for the temperature of the glass. An inclined asbestos screen above the furnaces, pierced by suitable holes to permit of inspection, deflected the hot air from the camera lenses. The camera took cinema film and had five 3 in. microscope objectives as tubes sliding in larger tubes for focussing. Cams on a clock shaft gave impulses to 2 solenoids, one which opened the shutter and the other closed it and set in motion the film-moving apparatus which, for 2 consecutive exposures, moved the film the length of one picture, and for the 3rd, the length of 13, to bring forward a clear piece of film for the whole length of the 5 objectives. This was brought about by a 15-toothed ratchet wheel having stops on 3 consecutive teeth. The specimens were illuminated by diffuse light scattered by the furnace walls from a source slightly off the axis. The degree and rate of devitrification of glass samples studied were judged by the quality of the photomicrographs and the rate of loss of definition. Photographs of the apparatus and some photomicrographs were given. (*Jour. Soc. Glass Tech. Abs.*)

Flashed glasses. W. H. *Keram. Rund.*, **33**, 698 (1925).—A transparent base glass was made from 30 sand, 35 red lead, 5 potash, 3 saltpeter, 3 calcined borax, and 20 parts glass frit of above batch. This was flashed with a white opaque glass made by substituting the saltpeter and borax by 4 parts tin oxide and 1.5 arsenious oxide. Sulphate glasses were difficult to flash, but the following were successful. Base glass from 480 kg. sand, 178 lime, 183 sulphate, 12.75 coke, 3 soda. This was flashed with a milk glass that could be melted in 5 hours from 45 kg. sand, 8.5 kg. soda, 3 kg. potash, 4 kg. cryolite, 10 kg. feldspar, 4.5 kg. fluorspar, and 200 gm. pyrolusite; or with an opal glass made from 100 kg. sand, 10 soda, 12 potash (80–85%), 16 limespar, and 18 soda. Another combination was an opal ground glass from 100 sand, 26 soda, 10 limestone, 18 feldspar, 8 cryolite, 8 fluorspar, and nickel oxide in suitable amount for decolorizing, with red glass made in a hot furnace from 100 kg. sand, 18 soda, 16 potash, 4 borax, 10 limestone, 2 tin oxide, 4 cupric oxide, 1.5 ferric oxide, and 1.5 pyrolusite. The copper and iron could be added as sulphates in aqueous solution. Green and blue flashed glasses were made upon an opaque white base glass melted from the batch 96 kg. sand, 14 potash, 16 soda, 16 feldspar, 11 fluorspar, 10 cryolite, and 2 zinc oxide. The batch for the colored glasses was 85 kg. sand, 20 soda, 10 potash, 15 marble, to which was added 2.5 copper sulphate and 75 gm. cobalt oxide for light aquamarine, 1.5 kg. potassium chromate and 2.5 kg. cupric oxide for light green, 5.5 kg. cupric oxide and 50 gm. cobalt oxide for new blue, or 3.5 kg. barium chromate and 1 kg. potassium chromate for green.

(*Jour. Soc. Glass Tech. Abs.*)

Drawing glass rod for ornamental and pressed ware. W. HANNICH. *Keram. Rund.*, **34**, 179 (1926).—Such rod was drawn by hand. Only small quantities were required and rods of many different colors were used. Hence they could only be worked from small pots of 120 to 170 kg. of glass. This prevented the economical use of the Danner method which wasted 20 kg. before drawing a good rod. Further, the licensee of the Danner method had to pay a royalty of 2½ cents per kg. rod produced. Several imitations of the D. method were known. In a Czechoslovakian patent that had not passed the experimental stage, the hot glass was poured into a vessel fitted with a nozzle. In running out through the nozzle it was shaped and immediately cooled by 1 or 2 air coolers. Neither the American nor the Czechslovakian method gave rod of uniform cross-section. The slightest variation of the temperature caused the glass to run into thin needles. It was especially difficult to employ such processes to produce rod 1–5 cm thick as required by the ornamental glass industry. A rod machine could not be used on a furnace without completely redesigning the latter. It was questionable whether the machine-made rod was suitable for subsequent working by pressing, cutting, etching, enameling, etc. Further, the sudden cooling of the glass from the furnace down to 700–800° or even lower might cause the glass to shatter when subsequently worked.

(*Jour. Soc. Glass Tech. Abs.*)

Opaque white glasses. V. S. *Sprechsaal*, **58**, 594 (1925); French Pat. 430,609.—Hydrated tin oxide having an alkali content of at least 3% had a good covering power for enamels and glasses. It was prepared by precipitation from a stannic solution, washing with water, and drying at a temperature not exceeding 100–140°. Experiments showed that with a composition of 80–85% SnO_2, 8–14% H_2O, and 3–5% alkali it had a greater covering power than ordinary ignited tin oxide. Calculating the tin as tin oxide necessary for equal covering power, 70 parts of this new material were equal to 100 parts of the old ignited oxide. (French Pat., 471,919.) A glass white by transmitted light was made by adding Al and F, the former in the greater quantity, together with a chloride. Bubbles, visible to the naked eye, existed and were stretched during the pressing and blowing. Heating had to be stopped before these bubbles disappeared. Good results were obtained from sand 100 parts by weight, lead oxide 15.625, soda 21.875, saltpeter 5.5, common salt 5.5, borax 1.25 to 2.5, hydrated alumina 18.12, and fluorspar 6. (British Pat. 148, 816.) By adding to a batch for pure white glasses, enamels, and glazes, sufficiently large quantities of fluorine compounds, natural ores of zirconium, tin, and beryllium could be used without the expense of previous purification. Example: 20 quartz, 35 feldspar, 10 soda ash, 5 magnesium carbonate, 10 crude zirconia, 20 sodium fluosilicate. Additional advantages claimed were high covering power, easy melting, glossier surface, large chemical and thermal resistance; boron compounds and decolorizing materials became unnecessary; low firing temperatures and sensitive ceramic bodies and porous bases were not cracked. (British Pat. 195,495.) Opaque glasses could be produced from glasses having a high silica content without the addition of fluorides, phosphates, or alumina as the following analyses showed:

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	71.5	75	75	75	78	80	80	80	76	85	85	90
B_2O_3	22.5	13	17	22	16	10	18	13.5	12	10	7	3
Na_2O	6	12	8	3	6	10	2	4.5	8	5	8	—
Al_2O_3	—	—	—	—	—	—	—	2	—	—	—	2
LiO	—	—	—	—	—	—	—	—	—	—	—	5
CaO	—	—	—	—	—	—	—	—	4	—	—	—

(*Jour. Soc. Glass Tech. Abs.*)

The question of the decolorization and discoloring of glass. E. ZSCHIMMER. *Sprechsaal*, **59**, 93 (1926).—A critical examination of the work of A. Cousen and W. E. S.

Turner on this subject. Z. confirmed the observation of W. J. Rees that arsenious oxide improved the color of glass made from carbon-containing sulphate batches, the cause being attributed to the oxidizing action of the arsenic on the sulphide. By analogy, the removal of the yellow selenium color by means of arsenious oxide was considered to be the suppression of the selenide by oxidation. Examples of the appearance of color in glass decolorized by various agents when exposed to light were quoted. Thus a soda-lime glass with 19.67% of alkali and 51.52% of lime, decolorized by selenium, showed a strong tendency to discoloration by electric light, while a potash-lime glass decolorized by nickel oxide and arsenious oxide developed a brown tint after 4 to 6 weeks in daylight. Strips of plate glass of a ferrous-iron bluish-green color became yellow on exposure to daylight, the change increasing with continued exposure. The cause was stated to be oxidation of the iron by oxygen dissolved in the glass, promoted by the ultra-violet rays. Such glass became once more bluish-green when heated in a muffle furnace at 550° and 600°. (*Jour. Soc. Glass. Tech. Abs.*)

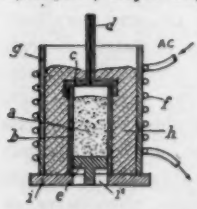
Phonolith in glass manufacture. ANON. *Sprechsaal*, **59**, 44 (1926).—In practice, the following advantages accrued from the use of phonolith as a batch material: (1) increased rate of production, (2) cheapening of batch costs, (3) production of a resistant glass. (*Jour. Soc. Glass Tech. Abs.*)

Phonolith in glass manufacture. A. BRASS. *Sprechsaal*, **59**, 145 (1926).—The basal constituents of phonolith were sanidin (geologically young orthoclase) aegirinaugite (a mixture of aegirine, $NaFeSi_2O_6$ and augite, $CaMgSi_2O_6$), hauyn ($3NaAlSiO_4$, $CaSiO_4$), nepheline ($NaAlSiO_4$), and magnetite (Fe_3O_4). From these constituents, sometimes sanidin or nephelene was absent, or nepheline partly replaced by leucite ($KAlSi_2O_6$). (*Jour. Soc. Glass Tech. Abs.*)

Phonolith in the glass industry. HUGO KÜHL. *Sprechsaal*, **59**, 217 (1926).—A reference to the results which K. had obtained by the use of 2 varieties of phonolith. (*Jour. Soc. Glass Tech. Abs.*)

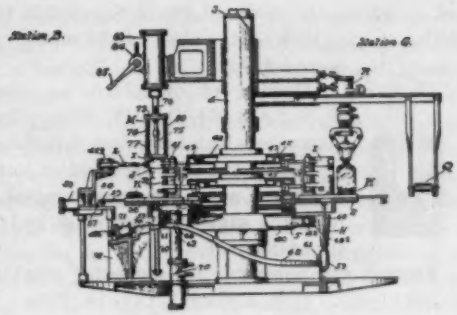
PATENTS

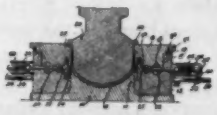
Apparatus for the manufacture of articles in silica glass. HENRI GEORGE. U. S. 1,601,523, Sept. 28, 1926. An apparatus for the manufacture of articles of silica glass, comprising a crucible of refractory and electrically conducting material adapted to receive the charge to be melted, a housing of electrically insulating material spaced from the crucible and surrounding the same, an electrically insulating and heat resisting material filling the space between the crucible and housing, a detachable draw-plate of refractory and electrically conducting material closing the crucible at its lower end, electrical high frequency induction means for simultaneously heating the crucible and the draw-plate, and means for expelling the charge, in a pasty state, from the crucible, through draw-plate. In an apparatus for drawing tubes according to foregoing, the provision, upon the cover of the crucible, of an axial tubular member extending within the crucible from one end to the other and bearing upon the detachable plug closing the lower end of the crucible, the tubular member being adapted to produce a bore in the charge expelled from the crucible.



Forming machine. THOMAS STENHOUSE. U. S. 1,601,836, Oct. 5, 1926. In a glass-forming machine, means for pressing a glass blank, and means for injecting a cooling medium for cooling selected portions of the blank, the cooling medium having a free exit to the atmosphere. In a glass-forming machine, a rotary table, a series

of sectional neck and body molds carried thereby, the neck molds being open at the charging station, a blank mold also carried by the rotary table, a track for elevating the blank mold to its pressing position, a carriage onto which the blank mold passes after leaving the elevating track, a supporting arm adapted to support the blank mold during the pressing operation, means for withdrawing the arm, and means for lowering the carriage when the pressing operation is completed. In a glass-forming machine, a rotary table, a series of sectional body molds carried thereby, a mold bottom slidably mounted on the table, a reciprocable plunger for moving the mold bottom into alinement with the body mold, and a cam track for withdrawing the mold bottom toward the periphery of the table.

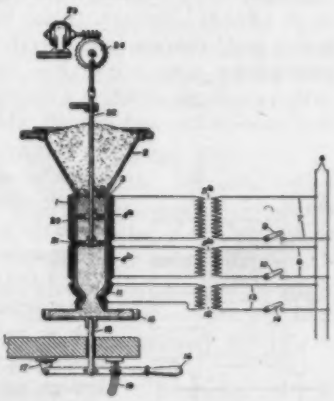




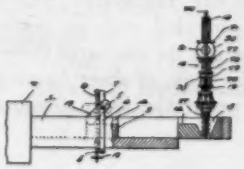
Glass mold. S. W. Gooch and W. K. Yonge. U. S. 1,602,012, Oct. 5, 1926. A glass mold comprising a plurality of mold sections pivotally connected at their ends, a series of articles forming depressions in each of said sections, a glass receptacle arranged between sections, grooves arranged in sections adjacent the depressions and communicating therewith, and means to force the glass from the receptacle to the grooves and depressions, whereby a plurality of series of articles will be formed, each series being connected to a boxing formed by the grooves.

Cutting apparatus for glass feeders. A. N. Cramer. U. S. 1,603,196, Oct. 12, 1926. The combination with means for flowing glass, of cutting mechanism for periodically severing the glass comprising shear blades, levers carrying the blades, a toggle connecting the levers, a pivoted support on which the levers are mounted, means to oscillate the support about its pivot and thereby swing the levers and toggle bodily into and out of a position in operative relation to the flowing glass, a lever arm fulcrumed on the pivot and connected to the toggle, and means to swing the arm and thereby actuate the toggle when in position and thereby actuate the shear blades.

Method and apparatus for making glass. Elihu Thomson. U. S. 1,603,221, Oct. 12, 1926. The method of making glass which consists in feeding glass-making material downwardly into a reaction zone, heating the material in the zone to fusion while protecting the upper zone of the material with unfused material and casting the material downwardly when a clear, glassy material has been formed.



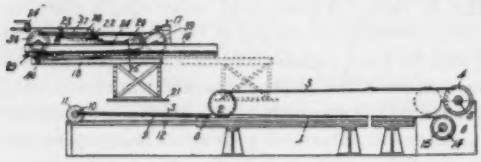
Apparatus for making glassware. J. J. Lentz. U. S. 1,603,479, Oct. 19, 1926. In an apparatus of the class described, means for regulating the flow of glass comprising a frame, a vertical shaft journaled for rotation in bearings on the frame, upper and lower friction driving disks carried by the shaft, a feed screw connected to the lower end of the shaft,



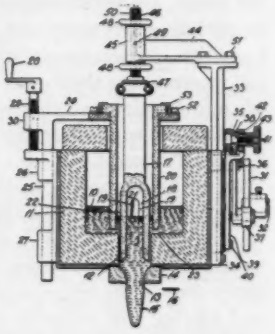
and an adjustably mounted motor disposed in close proximity to disks, there being a friction driving disk on the shaft of the motor coöperable with either one of the first-named disks.

Method of manufacturing stemmed glassware. G. S. DUNBAR. U. S. 1,603,524, Oct. 19, 1926. The method of manufacturing stemmed glassware which comprises depositing a charge of glass in a mold, moving an implement into the mold to form a blow blank, the same implement forming a stem and base integral with the blow blank from the same mass of glass and subsequently blowing the blank.

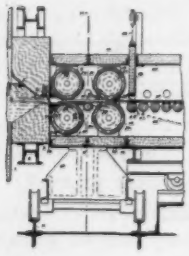
Process and apparatus for producing crackled glassware. D. L. MIDDENDORF. U. S. 1,603,552, Oct. 19, 1926. The method of manufacturing crackled glass ware which comprises impinging an atomized fluid upon the forming surface of a mold and then forming an article in said mold. Apparatus for producing crackled glass ware comprising a blank mold having a metallic forming surface, means for spraying the forming surface of the mold with atomized water to produce a crackled exterior surface on the blank to be formed therein, means for forming a glass blank in the mold, a blow mold, and means for blowing a blank positioned therein. The method of manufacturing crackled glass ware which comprises pressing a blank in a mold and forming a crackled surface thereon, and later blowing the blank so produced. In press and blow apparatus, a parison mold, and means associated with the mold for subjecting the glass to a chilling sufficient to produce crackling in the finished article.



Method and apparatus for producing plate glass. J. G. HAWORTH. U. S. 1,603,598, Oct. 19, 1926. In combination, a plate glass casting table, means for progressively flattening a batch of glass on the table, and a member movable over a portion of the table and the initially formed end portion of the glass plate for retarding the cooling of such portion of the plate.



Apparatus for feeding molten glass. K. E. PEILER. U. S. 1,603,862, Oct. 19, 1926. In apparatus for segregating mold charges from a body of molten glass, the combination with a container for the glass provided with a discharge outlet, of a member having an internal flow passage into and through which the glass can flow by gravity to the outlet, and means for reciprocating the member periodically to accelerate or retard the gravitational flow to the outlet.

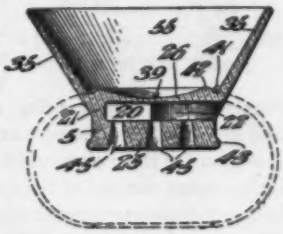


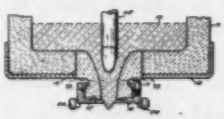
Apparatus for making sheet glass. FREDERICK GELSTHARP. U. S. 1,603,946, Oct. 19, 1926. In apparatus for making sheet glass continuously in a sheet or ribbon, the combination with a tank or receptacle for molten glass provided with an outlet through its side wall so located as to permit the discharge therethrough under the head pressure of the tank, of sheet forming rolls at such outlet with their pass under the head pressure

arranged to control the rate of flow of the glass from the outlet, and spaced apart a distance greater than the thickness of the finished sheet, and a second pair of rolls in advance of the first pair spaced apart a less distance than such first pair and serving to reduce the thickness of the sheet or ribbon.

Glass-forming apparatus. FRANK O'NEILL. U. S. 1,602,926, Oct., 12, 1926. Glassware forming mechanism comprising a first rotatable carrier, radially disposed guide way means mounted thereon, a bearing permitting movement of the guide way means as to the carrier, a sectional first mold mounted on the radially remote portion of the guide way means, means reciprocable in the guide way means in addition to the movement of the guide way means as to the bearing for opening the mold, an actuator as to which the guide way means is movable in the bearing, the actuator being operable to effect reciprocation of the reciprocating means in the guide way means, a second carrier eccentric of and rotatable relatively to the first carrier, a second mold on the second carrier for receiving glass from the open first mold on the first carrier, the second carrier mold being movable with the second carrier to approach the open mold on the first carrier, and driving means for rotating the carriers in synchronism to bring the molds simultaneously toward each other.

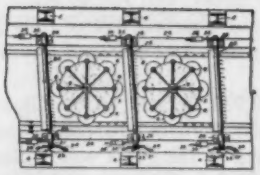
Method of molding glass and apparatus therefor. I. M. CLARKE. U. S. 1,603,025, Oct. 12, 1926. The method of molding a bowl of the character stated, which consists in molding a bowl blank having a frustrated conical wall, a bottom wall, and a hollow cylindrical member formed integral with the bottom wall and extending in a direction opposite to the direction of the frustrated conical wall, applying heat to the frustrated conical wall of the blank thereby plasticizing the same and lastly reversing the conical wall while in a plastic condition so as to cause the frustrated conical wall to surround the hollow cylindrical member. The method of molding a bowl of the character stated, which consists in molding glass in a plastic state around a central core and a series of spaced plugs at a right angle to the core, therewith forming an upper frustrated conical wall and a lower cylindrical member, withdrawing the series of spaced plugs thereby to leave behind a corresponding series of upright apertures in said cylindrical member, and withdrawing the central core member at a right angle to the direction of withdrawal of the plugs, thereby to leave behind a central inner chamber common to and interconnecting the upright apertures. In a mold of the character stated, a base plate, a joint mold mounted upon the base plate, core sections carried by the joint mold and extending inwardly to form a central hollow chamber, movable upright plugs extending through the base plate and connecting with the core section, and means normally to retain the plugs in a retracted position.



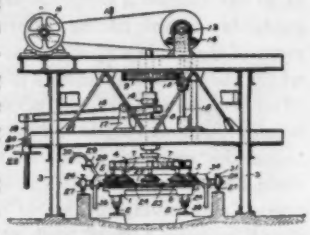


Means for forming charges of molten glass. L. D. SOUBIER. U. S. 1,603,160, Oct. 12, 1926. The combination of a container for molten glass having a restricted passageway terminating in an outlet orifice through which the glass is expelled, means to cause an intermittent discharge of glass through the orifice while the latter remains open, comprising a regulator within the glass, and means to cause a periodic movement of the orifice toward and from the regulator while the container remains stationary, the regulator being operable as the orifice moves toward it to force the glass outward and by the movement of the orifice from it to draw the glass inward.

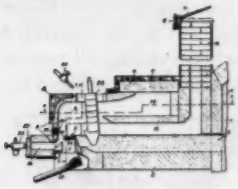
Apparatus for cleaning plate-glass polishing runners. H. S. HEICHERT. U. S. 1,603,949, Oct. 19, 1926. In combination in apparatus for polishing plate glass, a



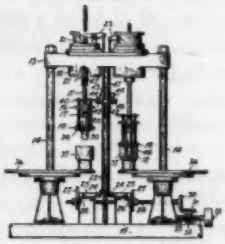
series of polishing machines, each having a rotatable frame provided with a set of polishing runners, means for carrying the glass to be polished beneath the runners of the series of machines, means for applying water to the machines to wash out the polishing material from the runners, fixed supporting means along the line of travel of the means carrying the glass on each side thereof, and shields between the machines extending across the glass to prevent the water employed in washing one machine from passing to the next machine, the shields being mounted upon supporting means for vertical movement so that they may be moved out of contact with the glass when the washing operation is not in progress.



Apparatus for cleaning plate-glass polishing runners. H. S. HEICHERT. U. S. 1,603,950, Oct. 19, 1926. Apparatus for use in cleaning a set of the vertically movable runners of a series of plate glass polishing machines mounted above means for carrying the glass there-beneath, comprising a washing pan adapted to receive a set of runners and mounted for movement longitudinally of the series of polishing machines intermediate the means for carrying the glass and the runners when the runners are raised.



Apparatus for conditioning molten glass. VERGIL MULHOLLAND AND K. E. PEILER. U. S. 1,603,974, Oct. 19, 1926. Glass conditioning apparatus, including a container for molten glass, a firing space, a baffle between container and space for directing heated gases over the bodies respectively; a helical spring; a plunger connected to the arms and movable in the spring's axial direction by the interrelative movement of the bodies, and having means adapted to tensioningly engage one end of the spring in the plunger's movement in one direction and means adapted to tensioningly engage the other end of the spring in the plunger's opposite movement.

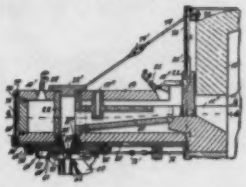


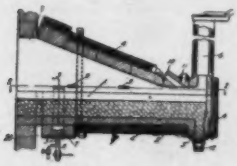
Plunger stop for glass presses. K. E. PEILER. U. S. 1,603,979, Oct. 19, 1926. In a glass shaping machine, the combination with glass pressing elements including a mold, of actuating means for moving one of the elements relative to the other to press glass in the mold, and means controlled by abnormal adhesion of glass to pressing means for discontinuing the operation of the actuating means.

Process of making sheet glass. LEE SHOWERS. U. S. 1,603,989, Oct. 19, 1926. A process of making a glass sheet, which consists in rolling a body of molten glass laterally into a sheet at a relatively high rate of speed, carrying the sheet thus formed ahead on constantly shifting separated lines of transverse support, and then decreasing the speed of forward movement of the sheet and exposing it to a progressively decreasing temperature to anneal it.

Device for discharging molten material. M. A. STEELMAN. U. S. 1,603,994, Oct. 19, 1926. In a device for discharging molten material, a furnace provided with an

opening for the exit of the molten material, a casing located exteriorly of the furnace adjacent to opening and provided with a downwardly inclined channel the upper end of which communicates directly with opening at the level thereof, a nozzle connected with the lower end of the channel, means for cutting off the supply of molten material at the upper end of channel directly adjacent to the exit opening of the furnace, and a cutter movable adjacent to the outlet of the nozzle. In a device for discharging molten material, a casing provided with an upright discharge chamber, means for supplying material to the chamber between its top and its bottom, a nozzle at the bottom of the chamber, and a removable cover, located in line with the nozzle, for normally closing the upper end of the chamber. In a device for discharging molten material, a furnace, a nozzle, means for conveying material from furnace to nozzle, and means permitting nozzle to be adjusted laterally toward and from the furnace.





Method and apparatus for delivering viscous glass. O. M. TUCKER AND W. A. REEVES. U. S. 1,604,000, Oct. 19, 1926. A spout for delivering viscous glass from a furnace comprising a body portion with a delivery aperture therein, and a removable cover block closing the top of the spout adjacent the delivery aperture, the block having a port therein which is adapted to direct temperature modifying fluid forwardly and downwardly into spout and to the glass adjacent to delivery aperture.

Glass batches. ANON. Eng. Pat., 245,131, Dec. 21, 1925. Aluminum sulphate is used to lower the melting point in sodium-aluminium borosilicate glasses. A glass for high voltage electric insulators consists of 81 parts of sand, 20 parts crystallized alumina sulphate, 28 parts borax, and 2 parts boric acid. (*Trans. Ceram. Soc.* [Eng.])

Heavy Clay Products

A. S. T. M. adopts standards for hollow tile. ANON. *Brick and Clay Rec.*, 69 [2], 120 (1926). F. P. H.

Lime pebbles no problem here. ANON. *Brick and Clay Rec.*, 69 [3], 189 (1926).—Description of a pebble remover and a shovel that digs from the top of the bank. F.P.H.

How New York's brick are made. ANON. *Brick and Clay Rec.*, 69 [3], 194 (1926).—Description of the soft-mud brick plant on the Hudson river. F. P. H.

Here it is—Hanley's new plant. ANON. *Brick and Clay Rec.*, 69 [5], 339 (1926).—Description of the new Hanley Co. plant at Summerville, Pa., built to produce 40 million buff and gray face brick annually. It was built on a basis of continuous operation for at least 40 years. F. P. H.

New rattler standards for thin brick. ANON. *Brick and Clay Rec.*, 69 [6], 425–26 (1926).—The tests conducted by the U. S. Bur. of Public Roads to establish percentages of loss in rattler for thinner sizes of paving brick are described. F. P. H.

Drying and firing in tunnel kiln. ANON. *Brick and Clay Rec.*, 69 [6], 433 (1926).—Time-temperature curve of tunnel kiln at Laclede-Christy Clay Products Co. is given. The drier end is 80 ft. long and the kiln proper is 331 ft. long, and has a capacity of 25,000 nine-inch brick every 24 hours. F. P. H.

Two and one-half inch pavers proven O. K. in test. ANON. *Brick and Clay Rec.*, 69 [7], 496 (1926).—Results of tests on paving brick of varying sizes made by the U. S. Bur. of Public Roads at Arlington, Va. The 2½-inch brick used in these tests, when properly supported proved satisfactory for pavements carrying the heavier types of traffic. A

bedding course of plain sand proved more effective in reducing breakage of brick than a cement-sand bedding course. F. P. H.

Making brick in Hoosierland. ANON. *The Clay-Worker*, **86** [3], 187–92 (1926).—A description of the new plant of the Standard Brick Manufacturing Co. F. P. H.

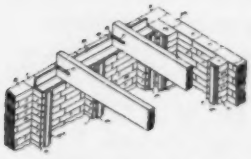
Discussion of specification requirements for common brick. C. O. CHRISTENSON. *The Clay-Worker*, **86** [3], 197–203 (1926).—C. presents a compilation of practically all available data on prescribed tests for brick and their respective relations to actual service. The tests were made at various times at different testing laboratories. The curves shown concern relations between compressive strength on edge and side, modulus of rupture, and absorption by boiling and by immersion. A summary of building code requirements made from a careful study of 115 city building codes is given. (Reprinted from *The American Architect*, July 5, 1926.) F. P. H.

Making eighty-thousand brick daily on ten-kiln plant. ANON. *The Clay-Worker*, **86** [3], 210–18 (1926).—Description of methods and uses at the plant of the Hill Brick Co. F. P. H.

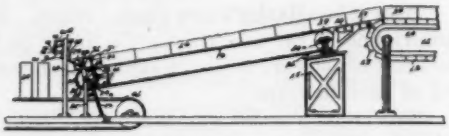
A new wall structure. ANON. *The Clay-Worker*, **86** [3], 222 (1926).—Description of the Richardson wall structure and claims made for this type of structure. F. P. H.

Brick clays. T. EASTWOOD. *Geol. Surv. Great Britain, Mem.*, **122** (1925).—Bricks of the highest quality are made from the Old Hill marl, and that formation is extensively quarried. The ferric oxide in the raw material not only colors the brick in firing, but also adds strength and hardness. In making Staffordshire blue bricks the clay is heated to such a degree that reduction of the ferric oxide and partial vitrification are produced. The resulting bricks have a glazed slag-like surface, are extremely hard and dense, and are only slightly porous. They are capable of withstanding such pressures as 483 tons to the sq. ft. before crushing. Details of the chief pits are described. O. P. R. O.

PATENTS



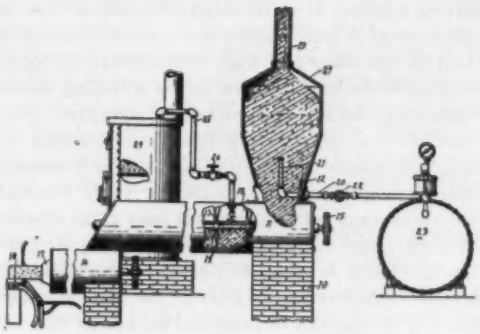
Brick wall construction. WILLIAM CARVER. U. S. 1,601,106, Sept. 28, 1926. A wall formed from a plurality of courses of standard size bricks and having a thickness equal to the width of one brick, certain of the courses having bricks at definite intervals arranged at right angles to define reinforcing columns and the other courses having a half-size brick interposed between right angularly disposed bricks in first-mentioned course.



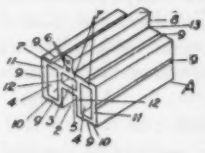
Off-bearing mechanism for tile-cutting machines. H. R. STRAIGHT. U. S. 1,602,719, Oct. 12, 1926. In a device of the class described, an endless conveyer designed to receive material from a tile cutting machine, a horizontally arranged conveyer beneath the discharge end of said endless conveyer and in alinement therewith, means controlled by the movement of the endless conveyer for gripping blocks carried thereby, and delivering them to the horizontally arranged conveyer from a substantially horizontal position to a vertical position.

Process for forming earthenware from pulverized material. H. R. STRAIGHT. U. S. 1,602,720, Oct. 12, 1926. The method of forming ware from pulverized material to be fired from shale and the like, which consists in first pulverizing the shale to a granular state, then subjecting the pulverized material to superheated steam of such

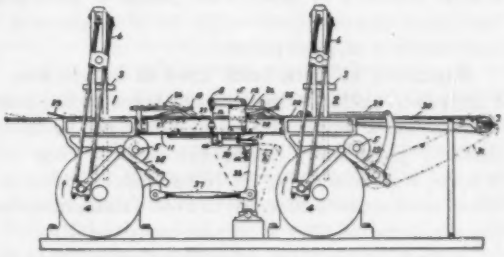
quantities as to raise the temperature of the mixture near or above the boiling point of water, then introducing water, pugging to the desired consistency, molding while hot, and drying.



Hollow-building-block wall construction. I. E. BARR. U. S. 1,603,891, Oct. 19, 1926. A hollow interlocking tile, comprising a body portion formed of hollow side sections and an intermediate section open at the bottom and provided with a transverse web forming with the top of the body portion a hollow section of less height than the side sections and wholly closed against the same, and a rib rising from the top of the body portion in line with and of less width than the intermediate section, the rib being formed with a longitudinal opening with its bottom wall in line with and forming part of the upper surface of the body portion, whereby to permit separation of the rib from the body portion without opening the intermediate section.



Brick sizer. J. H. TACKETT. U. S. 1,604,107, Oct. 19, 1926. A brick sizer comprising a press and a re-press, a blade, and a superposed roller interposed between the two presses and arranged with space between the blade and roller corresponding to the thickness of a trimmed brick, a tilting table having its free end disposed at the entrance to the space between the blade and roller, and adapted to be depressed by an untrimmed brick passing off the table and under the roller, thereby presenting the excess thickness of the brick below the blade, and means for feeding bricks delivered from the press along the tilting table, under the roller, over the knife, and to the re-press.



Refractories

Hand-made repressed fire brick. C. E. BALES. *Brick and Clay Rec.*, **69** [2], 125 (1926).—Precautions to use in making good hand made bricks. Effect of tempering is described. F. P. H.

U. S. Government Master Specifications for plastic fireclay refractories. ANON. *Brick and Clay Rec.*, **69** [6], 430 (1926). F. P. H.

The dissociation of dolomite. C. S. GARNETT. *Mineralog. Mag.*, 21–23 (1926). F. P. H.

Study of the decomposition of calcium and magnesium carbonates and dolomite. VICTOR J. AZBE. *Rock Products*, **29** [10], 57–59 (1926). F. P. H.

Foundry refractories. M. C. BOOZE. *Fuels and Fur.*, **4** [9], 1071–76 (1926).—The intermittent use of furnaces in the foundry industry makes the refractories requirements very severe. Cupolas require an abnormally dense lining material, capable of

resisting spalling to some extent, because of the unusually severe abrasion due to the large amount of iron oxide which comes in contact with the lining. With the combined action of the slags and high temperature, no ordinary refractory can be expected to last long in the melting zone unless a cooling device is employed. For the upper parts of the lining, refractoriness is not so important. No information is available on materials which are more suited than fireclay refractories for resisting abrasion in this service. These are usually made by mixing a small percentage of low-melting clay with high-grade clays, grinding fine, and firing hard. Flame impingement in itself does not produce abrasion of refractories, but may cause disintegration by depositions in the pores of the refractory, and also produce spalling stresses. Expansion may cause difficulties when the lining is built too closely to the steel shell. Rapid heating may increase the permanent expansion. In general, the more siliceous the material the greater the expansion, but the amount of potential expansion can only be determined by experiment. In building walls, the refractory lining may be placed directly in contact with the insulating bricks except in large furnaces, where a space should be left and packed with insulating powder. Modern insulating bricks make it possible to build a furnace of insulating bricks alone, if the structural load is kept small. Tight joints should always be obtained where possible. Wall thicknesses are determined by structural load, heat loss, rate of abrasion, and furnace temperature. A list, with short descriptions, of the factors effecting service, specifications for different parts of foundry furnaces, and of methods of testing is given. A.E.R.W.

Simplified practice applied to refractories. W. TRINKS. *Fuels and Fur.*, **4** [10], 1177–78 (1926).—A discussion of the possibility of reducing the number of "special shapes" as a first step toward simplified practice, followed by a reduction in the number of "standard shapes." It is pointed out that these economies have been effected in several instances in which steel plants or glass plants have been amalgamated and there is no reason to believe that the idea cannot be extended by the coöperation of all steel plants or all glass plants. A. E. R. W.

Expansion of silica brick used in tunnel kiln. CHAS. M. PEASE. *Ceram. Ind.*, **6** [5], 496–97 (1926).—Observations taken by engineers in charge of lighting and placing in operation a tunnel kiln for its initial use by the plant. The brick was heated very carefully particularly during the periods when silica was expanding most rapidly. A curve is given showing the rise of arch in inches as the kiln is heated. This particular silica construction conformed to Prof. Trink's observation (Vol. I, *Indus. Fur.*) regarding the expansion of silica in almost every detail. F. P. H.

A study of tests for refractories summarized in detailed report. S. M. PHELPS. *Amer. Glass Rev.*, **46** [1], 15 (1926); *Nat. Glass Budget*, **42** [23], 26 (1926). (Partially reprinted from Amer. Refrac. Inst., *Tech. Paper, No. 1*).—Descriptions of a series of load tests run on bricks to ascertain shortcomings of the tests and for the purpose of recommending new test procedures are given in considerable detail and results are discussed. Spalling test procedures specified by the A.S.T.M. and modifications thereof are enumerated, with discussion of reasons for modifications. E. J. V.

The durability of glasshouse pots. ANON. *Glass Ind.*, **7** [10], 236–38 (1926); (translated from *Keram. Rund.*, **34** [9], 142–44 (1926)).—The chief causes of excessive breakage of glasshouse pots are improper manufacture or faulty treatment during their use. The processes of proper manufacture are taken up thoroughly, all details being considered. A full discussion is given of the proper methods of using pots to increase their life. E. J. V.

The Ceramic Society; Refractories Materials Section. ANON. *Pottery Gaz.*, **51** [592], 1539–45 (1926).—A report of the autumn meeting of the Refractories Materials

Section of the British Ceramic Society held at Leeds University on Sept. 9 and 10. A proposed itinerary for the 1927 overseas excursion is given, as are short notes on the following papers presented: "A Further Note on the Influence of Iron Oxide in Promoting the Inversion of Silica," by W. J. Rees; "Practical Results and Experience in the Drying and Burning of Refractory Materials," by F. West and J. W. Fagan; "Refractories in the Gas Industry," by W. T. Gardner; "The Influence of Foreign Matter on the Thermal Expansion and Transformation of Silica," by J. W. Cobb, H. S. Houldsworth, and J. F. L. Wood; and "Modern Clay-working Machinery as Used on the Continent," by H. M. Ridge. E. J. V.

The study of glass tank blocks. ANON. *Pottery Gaz.*, **51** [592], 1573–74 (1926).—An enumeration of various properties of tank block studied in an investigation by the Bureau of Standards. Conclusions drawn from data obtained are: (1) corundum and mullite, under the physical conditions existing at the contact of tank block and molten glass, resist solution better than other refractory materials; (2) the physical structure of the block should be homogeneous, with small pores, closed or non-connecting, and with a minimum of interstitial glass; (3) the solution of submerged portions of the block is due to accelerated attack of the glass on the upper surfaces of the pores, cracks, and laminations rather than to erosion due to movements in the main body of the glass; and (4) due to the decreased viscosity of the glass and the increased solubility of the tank block constituents at temperatures above 1450°C, the life of tank block may be expected to be materially shortened. E. J. V.

Refractory materials and slag corrosion. A. DALE. *Iron and Coal Trades Rev.*, **113**, 463 (1926).—Testing of refractory material for resistance to slag corrosion and erosion. The main aim of the report is to recount what has already been achieved by previous workers in this field and to suggest some scheme of attack in this direction, which the British Refractories Research Association expects to be able to develop in the near future. The corrodibility of a given brick by a given slag under special industrial conditions is governed by numerous influencing factors, *i.e.*, the chemical and mineralogical constitution of the brick, and also its penetrability; the cohesion between grog and matrix, and the degree of internal strain; the nature, constitution, etc., of the slag, the prevailing temperature and atmosphere; temperature irregularities, and temperature gradients through the refractory material; the internal contour of the furnace or flue, insofar as this controls or restricts density and convection movements in the melt; the structural stresses encountered; the type of jointing materials used. Many of these factors are, however, of a purely industrial nature, and may be regarded as accelerating the fundamental phenomena, rate of solution, and erosion per unit area of slag brick contact. This suggests that laboratory methods of investigation, which would evaluate the progressive rate of corrosion and erosion of different bricks by different slags at 3 or 4 different high temps. should provide results of fundamental significance, and hence of definite industrial value. It is along these lines that the Association hopes to develop further the work recounted in this paper submitted, at the London meeting of Gas Engineers, by Refractory Materials Joint Committee. O. P. R. O.

The Ceramic Society. ANON. *Chem. and Ind.*, **45**, 720–21 (1926).—The Autumn meeting of the Refractory Materials Section was held at Leeds, Sept. 9 and 10. Papers read were: "Influence of Iron Oxide in Promoting Inversion of Silica," by W. J. Rees; "Drying and Burning of Refractory Materials," by West and Fagan; "Refractory Linings for Cement Kilns," by G. Martin; "Influence of Foreign Matter on Expansion and Transformation of Silica," by Wood, Houldsworth, and Cobb; and "Modern Clay Working Machinery as Used on the Continent of Europe," by H. M. Ridge. H.H.S.

Fractional fusion of refractories. R. HUSTIN. *Chim. Ind.*, **14**, 691 (1925).—The problem of fusion in furnace refractories is studied by reference to an experience in

actual works practice. Special bricks used for lining a re-heating furnace and which gave good service were found to have undergone partial fusion during the first 8 days, after which no further fusion took place. The phenomenon was especially apparent in the hearth of the furnace in contact with the coal. Only the exposed surface of the bricks was attacked, the rest of the brick remaining intact. The unaltered part contained: 78.80 SiO_2, 18.28 Al_2O_3, 2.47 Fe_2O_3, 0.56 CaO, and 0.26 MgO, whereas the fused surface portion analyzed as follows: 56.30 SiO_2, 31.53 Al_2O_3, 8.97 Fe_2O_3, 2.17 CaO, and 0.62 MgO. This remarkable decrease in silica and simultaneous increase in alumina and fluxes points to the assumption that the change is due to loss of silica. The fluxes introduced by the coal reacted with the silica (probably with the free silica) to form silicates having relatively low melting points. This is confirmed by the slow fusion observed during the first 8 days. After the removal of these fusible silicates, the exposed surface of the brick has become richer in alumina, and this protective surface accounts for the improved service given by the brick. Simple mathematical treatment of the figures for the two analyses given above indicates that practically all the free silica, amounting to about 50%, disappeared in the form of fusible silicates. The reaction might also take place without the intervention of outside influences (fluxes); the free silica might form fusible silicates with the fluxes in the brick itself. This would produce an improvement in the lining, (1) by causing a slight increase in the alumina content, and (2) by the elimination of the fluxes. It is assumed that this reaction, which takes place at any given surface, will be repeated at adjacent surfaces, in which case the fusion process would be as follows: The surface exposed to the fire becomes rich in alumina and covered with a protective coating. Fusion of the latter takes place slowly, when a new surface becomes exposed. The process is then repeated, until finally the whole brick disappears. (*Trans. Ceram. Soc.* [Eng.])

Studying and testing refractory materials for the metallurgical industry in Germany. E. H. Schulz. *Stahl u. Eisen*, **45**, 1733 (1925).—The demands made upon refractories for the metallurgical industry may be summarized as follows: Refractoriness, a cone-melting-point of cone 26 at least (1600°); resistance to mechanical strain, usually pressure; constancy of volume exposed to abrupt changes of temperature, *e.g.*, bricks for ladles, copper stoves, and regenerators; thermal conductivity; chemical stability to resist slags, furnace gases, coal and flue dust. Results which can be expressed numerically are of the greatest utility. Silica bricks should have a prescribed minimum silica and maximum flux content. Iron content is important with bricks in contact with carbon monoxide, *e.g.*. in the blast furnace. Of greater importance than the total iron oxide content is the manner in which it occurs, whether in spots, etc. Hence, the chemical analysis is of limited value only. The cone-melting point test on powdered material merely indicates effect of temperature, whereas, in practice, other factors invariably come into play. The results of the refractory under-load test are modified to some extent by the so-called "fire skin." The results of comparative tests are as follows:

Type of brick	Full cylinders, especially formed and fired	Full cylinders cut out of bricks
Silica I	1630°C	1615°C
" I	1610	1590
" II	1570	1540
" II	1595	1580

The effect of the "skin" appears to raise the softening point by about 15 to 30°. Test pieces should be in solid cylindrical form, 50 mm. (1.96 in.) in diameter and height, and the load, 2 kg. per sq. cm. (28 lb. per sq. in.). Effect of varying load on the softening point is shown by the following:

	Kg/cm.²	Brick lb./sq. in.	*A* °C	*B* °C	*C* °C
Load	1	14	1626	1549	1534
	2	28	1609	1530	1530
	3.5	50	1604	1515	1475

The rate of heating is also important; for silica bricks, it should be particularly slow (2 to 3 hours) up to a temperature of 500–600°. Porosity is important to resistance to temperature changes, but the reverse is true in relation to resistance to chemical action. When resistance to both these factors is demanded, *e.g.* in ladles, intermittent furnaces, etc., it must be remembered that a dense material will crack badly if exposed to abrupt changes of temperature, and will then be far more susceptible to attack by chemical agents. The specific gravity of silica bricks affords an indication of the degree of transformation of the quartz and should be determined exactly to the third place of decimals. Degree of quartz conversion is also determined by measuring the volume changes on heating. The presence of tridymite in a silica brick is the best guarantee of its resistance to changes of temperature. For determining the important property of structure, the Steinhoff staining test is recommended. Resistance to abrupt changes of temperature is determined by the quenching test. Resistance to chemical attack must be tested on whole bricks exposed to the action of slags, etc., under conditions resembling those of actual practice. Tests in which holes are bored in the bricks and filled with slag, or in which small pieces are exposed to the molten slag are not reliable. A special furnace has been constructed for carrying out this and other tests. It is a type of metallurgical furnace, in which the hearth can be constructed in various forms. A temperature of 1650° can be maintained without difficulty for weeks at a time. The furnace is suitable for determining (1) the consistency of volume and degree of quartz conversion in silica bricks; (2) the resistance to slag attack; (3) resistance to quenching, for which test bricks are built into a door frame, treated in this way, and then cooled simply by removing the whole door into the open air and spraying. Standard tests should include the following: (1) chemical analysis, which still retains a certain significance; (2) refractoriness under-load, although for some purposes, *e.g.*, ladles, this is not of paramount importance; (3) determination of porosity; (4) determination of volume changes on heating (and cooling) up to at least 1500°; (5) the prism melting test in place of the cone melting test, prisms cut out of bricks being substituted for cones made of the material; (6) examination of the structure. The Standard Specifications, as now in use in various countries, are examined in the light of the above. The values for the various tests for German refractory materials are given in the form of "frequency curves," in the case of silica material. This was found to be impossible in the case of fireclay bricks, owing to the great variations between the various types. The frequency curves for silica bricks showed, in most cases, a well-defined maximum, indicating the value, or values, for the various tests which occurred most frequently out of a large number of tests. Reduced to tabulated form, a study of the curves supplied the following information:

Property Chemical composition	Minimum	Maximum	Maximum on curve, i.e. frequency
Silica content	90.5%	96.5%	94–95%
Lime	1.25%	3.75%	1.5–2%
Iron (Fe_2O_3) content	0.3%	3.7%	1.0–1.5%
Alumina content	0.25%	3.7%	2.5–3%
Cone melting-point	Cone 28½	33½	Cones 32–33
Porosity	12%	33%	20–25%
Specific gravity	2.32	2.6	2.37–2.52
Softening point under load (3.5 kg/cm. = 50 lb. per sq. in.	1460°	1640°	1535–1610°

Information respecting the degree of firing, *i.e.*, of quartz conversion is given by the specific gravity curve. In this curve, no well-marked maximum frequency was found. All degrees of quartz conversion occurred; there were bricks in which the quartz was practically unaltered and others which consisted almost entirely of tridymite and cristobalite. In the majority of cases from 41 to 87% of the quartz has been converted. Similar observations were made with regard to the softening-point under load, a well-defined maximum frequency did not occur. Under a load of nearly 50 lb. per sq. in., the majority of bricks softened between 1535 and 1610°, but certain bricks softened even below 1500°, a temperature which is certainly too low for many purposes. This plainly shows that uniformity in the results of the cone melting-point test by no means implies a similar uniformity in the results of the under load test.

(*Trans. Ceramic Soc.* [Eng.]).

Silica material in gas works. J. PRETSCH. *Feuerfest*, **1**, 80(1925).—The successful substitution of silica for fireclay material in a gas works is reported. Two oven walls were first built of silica materials and put into operation in 1913. Very favorable results were immediately apparent; the time taken to gasify the coal in this trial oven was shorter by 3 hours than that required in the firebrick ovens, the temperature and the type of coal being the same in both cases. In consequence of this improvement, a complete oven was built exclusively of silica material in 1914, and in another case the firebrick material was gradually replaced by silica, without reducing the width of the oven. Using the same type of coal and applying the same temperature and coking period, the gas produced was increased by about 20 cu. m. per ton of coal. Neither in the flues nor in the walls was there any melting of the silica material, although the temperature occasionally reached 1550°C. Considerable variations in the quality of different silica materials were observed during the course of the investigation, and it is concluded that only a test under working conditions can give a really reliable indication of the suitability of any given material. Careful records showed that the average life of silica brick walls is about 7 years of uninterrupted service. The general conclusions drawn from the results of the investigations are as follows: Silica has a much higher thermal conductivity than fireclay material; consequently, the gas yield is greater, and the coking period is shorter. Silica bricks are more refractory; they resist high temperatures (up to 1550°) without softening or melting. The life of coke ovens built of silica material can be reckoned at 2500 to 3000 working days. The cost of repairs is lower in the case of the silica oven than for the firebrick structure, owing to the greater refractoriness and mechanical strength of the silica brick. A disadvantage of the silica material is its tendency to expand or contract each time the oven is put into operation or closed down. But in spite of this undesirable property, the advantages of silica over fireclay material are so considerable, that, in the future, it will be considered the proper thing to build the walls of coke ovens of silica bricks only.

(*Trans. Ceram. Soc.* [Eng.])

"Carboplastic": a new refractory. ANON. *Gas Jour.*, **173**, 204(1926).—The principal ingredients of the new cement are Carborundum and suitable bonding materials. It requires the addition of water only, and it sets in air with a strong bond.

(*Trans. Ceram. Soc.* [Eng.])

Physico-chemical investigation of Borowitz refractory clay. G. G. URASOV. *Z. anorg. Chem.*, **154**, 152–69(1926).—The Borowitz clays vary in ceramic properties from "biscuit" with very little plasticity to highly plastic soft porcelain. All these clays when heated show halts at 110° and at about 600°, corresponding with loss of free and combined water, and a further sudden rise of temperature at 950° due to an exothermic reaction. The halt at 600° is less abrupt for the more plastic clays, corresponding with a more gradual loss of water, and the irregularity at 950° is also less pronounced. When

a current of dry air is passed over the clays, heated at a constant temperature, the loss of water from the least plastic clays is about 3% at 110° and 24% at 387°, and from the plastic clays 13–22% at 110° and 47% at 387°. A large proportion of the water is evolved at about 400° and at 425° over 90% has been lost from both classes of clays. The higher temperature indicated by the heating curves for the loss of combined water is due to the systems not being in equilibrium when heated comparatively rapidly. If the combined water were water of crystallization the whole would be lost at the same temperature, whereas the loss from colloidal substances is gradual. The loss from the non-plastic clay corresponds fairly closely with the former and that from the plastic clay more with the latter. The following scheme is proposed to represent the loss of water in three stages: 100–400°, $a\text{-}Al_2Si_2O_7$, $nH_2O \rightarrow a\text{-}Al_2Si_2O_7$, $xH_2O + (n-x)H_2O$; 400°, $a\text{-}Al_2Si_2O_7$, $n_1H_2O \rightarrow \beta\text{-}Al_2Si_2O_7$, $mH_2O + (n_1-m)H_2O$; 400–600°, $\rightarrow \beta\text{-}Al_2Si_2O_7$, $yH_2O + (m-y)H_2O$; at 600° y is zero. The first and last systems are univariant and equilibrium is possible over a range of temperatures; the second system is non-variant. X-ray examination of the clays showed no marked differences in structure.

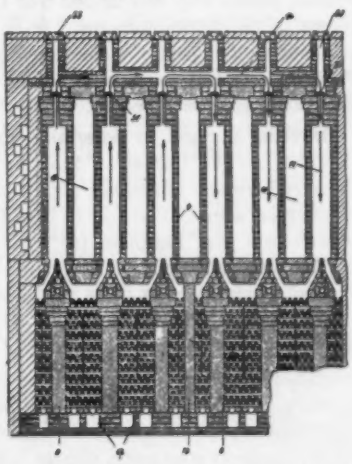
(*Brit. Chem. Abs.*)

Temperature-sensitiveness of refractory materials in the glass industry. K. ENDELL AND W. STEGER. *Glastech. Ber.*, **4**, 43–57 (1926); *Chem. Zentr.*, II, 480 (1926).—K. and S. define temperature-sensitiveness as equal to the quotient of the coefficient of thermal expansion by the torsional power at 500–600°. The thermal expansions of silica bricks and tank blocks, and the heat conductivity of a highly siliceous tank block were determined. The tendency to splitting was determined by heating 3 bricks in a gas furnace upon one side only to 850°, and then plunging into water, the process being repeated until the brick broke. Quartzose bricks split after 1 to 3 quenchings, but some samples withstood over 15 tests. Bricks were temperature-sensitive only below 600°. (*Brit. Chem. Abs.*)

PATENTS

Refractory products and their manufacture. F. C. F. LE COULTRE. U. S. 1,602,273, Oct. 5, 1926. A process for the production of refractory products from zirconiferous ores, consisting in treating the ores to a very high temperature in an electric furnace with a circular enclosure, and in precipitating the ores when they leave the furnace into a violent stream of cold water acidulated with 1/1000 sulphuric acid.

Coking retort oven. MAX SOMMER. U. S. 1,603,992, Oct. 19, 1926. A coking retort oven comprising in combination, a series of coking chambers arranged side by side with the intermediate walls thereof common to the contiguous chambers, each of the walls containing a row of vertical combustion flues, regenerators underneath and communicating with combustion flues at the bottoms thereof, a bus flue above the chambers and communicating with combustion flues at the tops thereof and regenerator connection connecting at least 4 such rows of combustion flues to form a separate group or unit in such manner that flow may take place in one direction in all of the flues of all of the contiguous rows of combustion flues of one-half of such rows of flues of the unit and in the opposite direction in all of the flues of the contiguous rows of combustion flues of the other half of the rows of combustion flues of the same unit.



Silica bricks. N. SCHÜLLER. Eng. Pat., 249,543, Mar. 20, 1925. Waste sands, *e.g.*, for glass making, grinding, and washing processes, etc., are used instead of quartzite, being mixed with slaked lime, with or without organic binders and pieces of quartzite, and subjected to super-heated steam, hot gases, or hot air. Rapid formation of tridymite is said to take place. (*Trans. Ceram. Soc.* [Eng].)

Siliceous refractory materials. A. TRIPPENSEE. Eng. Pat., 247,994, Feb. 20, 1926. Portland cement is used as the binding material for refractory substances such as grog, quartzite, sandstone, sand, etc. The mixture may be used either to build up furnace linings directly *in situ*, or it may be pressed into bricks or blocks, which do not require to be fired. (*Trans. Ceram. Soc.* [Eng.])

Refractory bricks. R. H. YOUNGMAN. Eng. Pat., 250,480, Oct. 24, 1925. An unfired brick is molded from a mixture of 60% calcined magnesite, 35% chrome ore, and 3–10% sodium silicate. (*Trans. Ceram. Soc.* [Eng.])

Terra Cotta

From backyard shop to world's best. ANON. *Ceram. Ind.*, **6** [5], 488–91 (1926).—A description of the St. Louis plant of the Northwestern Terra Cotta Co. F. P. H.

White Wares

Vitreous china sanitary ware clays. GORDON P. GAVIN. *Ceram. Ind.*, **6** [5], 487 (1926).—G. claims that domestic clays are inferior to English clays. F. P. H.

Porcelain plant uses evacuated slip. ANON. *Ceram. Ind.*, **7**, [4] 351–57 (1926).—Description of the methods and equipment used at the plant of the Lapp Insulator Co. A special type of disintegrator reduces the clays for blunging, tearing them into uniformly small pieces. The blunged slip is purified and the whole body is blunged and lawned, after which it is ground for several hours in pebble mills. Then the slip is lawned again before it runs into the pump cistern. From this pump cistern the slip does not go directly to the pump, but flows under control, by the reduction in pressure, into a vacuum treating tank where the air bubbles that have been ground into the slip are expanded and liberated. The removal of this air from the slip before it enters the filter presses to become plastic clay has helped this Company to eliminate some of the difficulties inherent in the plastic process. It is asserted that the better plasticity and working qualities are but part of the improvements realized by removal of the air from the slip. Thorough vitrification is accomplished more readily: the density and strength of the fired porcelain are increased. F. P. H.

Develop method to determine hardness of glazes. ANON. *Ceram. Ind.*, **7** [4], 357 (1926).—The Bureau of Standards has developed a method for determining the abrasive hardness of ceramic glazes which may be used to compare different brands of commercial ware. Tests on 10 brands of hotel dinner plates, 4 foreign and 6 domestic, demonstrate that hardness (*a*) varies in direct proportion to the silica content; (*b*) reaches alternate maximum and minimum as alumina content is increased, and (*c*) reaches a maximum as glaze thickness is increased. F. P. H.

Pottery waste: some important applications. E. T. ELLIS. *The Clay-Worker*, **86** [3], 192–93 (1926).—The following uses of waste are suggested: (1) manufacture of insulation slabs for ice making machinery, (2) biscuit pottery as a source of tooth powders, (3) broken earthenware in concrete construction, (4) useless junk as an ingredient of artificial stone, (5) waste pottery as a filler for india-rubber and paper, and (6) well-ground waste as a diluent for soil fumigants and fungicides. F. P. H.

Making "Supertile" in California. ANON. *Rock Products*, **29** [2], 81–82 (1926).—Sunset Tile Company makes a new form of poured tile which is cured in the mold. F. P. H.

A review of the Russian pottery industry. A. LUSIN. *Pottery Gas.*, **51** [592], 1563–64 (1926); (translated from *Keramika i Steklo*).—The existence of the Russian porcelain industry which began with the establishment of the Imperial Porcelain Factory in 1744 is reviewed. E. J. V.

The new home of Haviland china is the last word in showrooms. ANON. *Pottery, Glass, and Brass Salesman*, **34** [11], 19 (1926).—A complete description of the new home of Haviland china at Broadway and Twenty-fourth St., New York. E. J. V.

The relationship between the constitution and the properties of porcelain. R. RIEKE. *Ber. deut. keram. Ges.*, **6**, 144 (1925).—The structure of a fired porcelain body usually presents the appearance of a glassy (feldspathic) matrix, in which crystals of mullite ($3Al_2O_3.2SiO_2$) and quartz are more or less finely distributed and which is permeated with minute pores due to air bubbles. This general structure varies in detail in different porcelains; the mullite and quartz crystals vary both in quantity and in size. In an ordinary hard porcelain the properties are mainly determined by the nature of the matrix. A large portion of the crystalline quartz and part of the mullite are dissolved in the feldspathic flux and so form part of the matrix. The proportion of the latter is thus increased considerably; in ordinary porcelains it usually forms much more than one-half of the body, which, in consequence exhibits many of the properties of a highly siliceous glass. Depending upon the firing treatment and similar factors, the matrix may vary in composition as follows: 78–86SiO_2, 11–8Al_2O_3, 10–6K_2O, omitting materials present in small quantities, such as magnesia, sodium, iron oxide, etc. The composition, 86SiO_2, 8Al_2O_3, 6K_2O represents the optimum theoretical conditions, when all the quartz and 10–15% of the mullite have been dissolved. The nearer the porcelain approaches this optimum in composition, the better its physical properties, *e.g.*, low coefficient of expansion, great resistance to heat and chemical reagents. But the homogeneous nature of the matrix is interrupted by the presence of crystals of mullite and of undissolved quartz embedded in the matrix. The properties of the body are modified considerably not only by the quantity, but also by the size and the distribution of the crystalline components. Porcelain containing large quartz grains in flaky form will exhibit uniform mechanical properties. The quantity of mullite crystals present in a porcelain body is the chief factor in determining the mechanical properties, though the size and distribution of these crystals are also of almost equal importance. The mullite crystals should preferably exhibit a fine-grained formation, the structure then having appearance of a felty network of crystals of acicular form. The resistance to abrupt changes of temperature depends upon a number of factors, the chief being the coefficient of expansion. This property is, therefore, best developed in a porcelain having a matrix rich in alumina and silica, little free quartz, and containing fine mullite crystals uniformly distributed throughout the body. Similar considerations apply to the property of strength or toughness. Other conditions govern the development of translucency. Quartz and mullite crystals, and air pores, have the effect of "opacifying media"; the formation of these must, therefore, be inhibited as far as possible and the production of a clear fused matrix encouraged. The methods by which the desired body structure can be produced and existing porcelains improved are discussed in broad outline. The quality of the matrix is affected by the kind of feldspar used, its varying content of potassium, sodium, lime, and silica, etc. The addition of small amounts of lime, magnesia, zinc oxide, etc., reduces the viscosity of the matrix and promotes the formation of large mullite crystals, thus increasing the translucency of the fired body. These additions, however, increase the coefficient of

expansion and thus reduce the resistance to changes of temperature considerably. Attempts have been made to reduce the expansion by substituting artificial frits for the feldspar of the matrix, but hitherto without marked success. With regard to the quartz it will, in general, be desirable to develop a porcelain in which only small quartz grains are visible under the microscope. To achieve this, the quartz must be ground as fine as possible, the ware must be fired for a long time at a high temperature, and further, the above-mentioned additions may be made to the body in order to accelerate solution of the quartz in the matrix. The origin of the quartz used is also important; any siliceous material containing close upon 100% SiO_2 is not necessarily suitable for making porcelain. The degree of mullite development in porcelain body is influenced by the type of kaolin used. Relatively coarse-grained kaolins, like English chinaclay, produce more translucent bodies than finer-grained plastic koalins under identical conditions of firing, etc., owing partly to the formation of larger mullite crystals. The conditions (minimum temperature, etc.) under which mullite can be developed in a body have not been accurately determined. It has been identified in bodies fired to 1200°, but it develops rapidly with rising temperatures.

(*Trans. Ceram. Soc.* [Eng.])

Impurities (discolorations) in fired porcelain. HACKELOER-KÖBBINGHOFF. *Ber. deut. keram. Ges.*, **6**, 236 (1925).—The causes to which discolorations in fired porcelain are due are discussed. Pyrite is frequently present in kaolins having a high percentage of sand (*i. e.*, insufficiently washed). The composition of the original rock and the mode of kaolinization largely determined whether, and in what form, pyrite is present. Feldspar may contain micaceous impurities; iron-containing biotite, and chloride micas in particular, must be carefully eliminated. The water used in grinding, or in making operations, if not fresh, may be contaminated with filamentous algae, minute iron secreting organisms, the cells of which cause "iron spots" in the fired ware. Rust may be introduced by iron piping, whether galvanized or not. Grinding pans should be lined, and the lining cemented with material containing only traces of iron. German "Findlings" quartzite is not suitable. Excessive weathering or aging of porcelain body mixtures also leads to rapid production of filamentous algae. Aging, particularly of bodies rich in "fat" clays, should not exceed 6 months. Compressed air, used for cleaning biscuit ware, may absorb moisture contaminated with iron, etc., from the pumps. In the firing of body mixtures, which have been insufficiently ground, deposition of carbonaceous matter frequently occurs during the reducing period.

(*Trans. Ceram. Soc.* [Eng.])

(Electrical) shock-testing of insulators under water. M. TOEPLER. *Keramos*, **4**, 29 (1925).—Under oil, the top of a porcelain insulator becomes charged negatively, under water, positively. In air, powerful discharges are observed from the metal cable to the adjacent surface of the insulator. Under oil, this equalization of the electric field is prevented; consequently, great stresses occur around metal caps, rings, supports, etc. In water, the powerful field toward the surface is missing; new types of breakdown of the porcelain material have to be reckoned with, such as occur from water through porcelain to water, there being no contact with metal supports, etc., *i. e.*, there is no short circuit. In general, the porcelain body is subjected to a more uniform stress under water than under oil. Shock testing under water is, therefore, to be preferred. The method of conducting a test is described. (*Trans. Ceram. Soc.* [Eng.])

Tests on the translucency of porcelain. R. RIEKE AND K. SAMSON. *Ber. deut. keram. Ges.*, **6** (1925).—The translucency of porcelains was measured with a photometer by a method previously described. The nearer the refractive index of substances embedded in the matrix of a porcelain approaches that of the matrix itself, the less the opacifying effect of such substances. The refractive index of the matrix of hard porce-

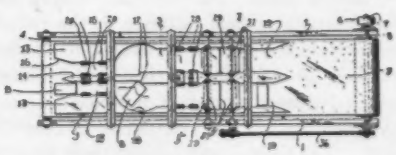
lain is 1.48, of mullite crystals, 1.64, and of quartz crystals, 1.54. Mullite has, therefore a greater effect upon translucency than quartz. Within limits, a simple relationship exists between thickness of specimen and translucency. Nineteen bodies were prepared and tested, the compositions varying from 40–60% clay substance, 15–35% quartz, and 15–35% feldspar. The raw materials were: washed kaolin (Sedlitz), Norwegian feldspar, and Hohenbocka sand. In general, the translucency of porcelain is increased by raising the firing temperature and by increasing the feldspar content at the expense of the quartz, the clay substance content remaining constant. The highest translucency values were obtained with bodies containing 40–50% clay-substance, 15–30% quartz, and 30–35% feldspar. Repeated firing to the same temperature reduced the translucency by increasing the mullite formation. The well-known Seger porcelain (low clay-substance content) is much more translucent when fired to cone 12 instead of cone 10. Bodies prepared with kaolins of different origins exhibited marked variations in translucency. The use of china clay instead of Sedlitz kaolin considerably increased the translucency. Different kinds of raw quartz also affect the translucency. Best results were obtained with Norwegian vein quartz, which was converted almost entirely into cristobalite after one fire in a porcelain oven to cone 15. The more finely ground the quartz, the better the translucency. The effect of pegmatite, when substituted for feldspar and sand, varied considerably, some varieties giving improved results, others the reverse. The additions of small amounts of lime or magnesia increased the translucency, whereas iron oxide had the opposite effect. Preliminary fusion of the feldspar with the quartz produced bodies of exceptional translucency. By fritting together the necessary quantities of feldspar and quartz so that all the quartz was dissolved, and using the resulting frit to prepare porcelain bodies with Sedlitz kaolin and English china clay, the translucency figures were 312 and 370 respectively (Seger porcelain 230). (*Trans. Ceram. Soc.* [Eng.])

Change of the cone drop point of pottery glazings with varying chemical composition. E. ZSCHIMMER AND E. LEONHARDT. *Z. tech. Physik*, **7**, 287–90 (1926).—Cones were prepared of known composition and structure and their collapse temperatures determined according to a definite heating method. For every heating rate of $v°$ per minute a certain temperature t defines the drop point of a cone of some particular composition ($v = 6°$ per minute was mostly used). Admixtures of SiO_2, B_2O_3, Al_2O_3, PbO, CaO, etc., to the glazing material were tried out. Na_2O, PbO, and B_2O_3 lower t in the order mentioned (for 25% addition of each, respectively, from 720° down to 590°, 660°, and 670°); Al_2O_3, CaO and SiO_2 raise t to 835°, 795°, and 750°. (*C. A.*)

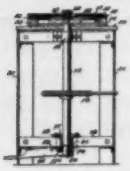
Earthen ware and its use in chemical industry. P. MÜLLER. *Teknisk Tids.*, **56**, (Kem. afd.), 6–8, 13–15, 21–23, (1926).—An instructive article mostly descriptive with 34 line drawings of pottery appliances including parts fitting into metal apparatus. The physical properties are: tensile strength 50–80 kg. per sq. cm; compressive strength 1500 kg. per sq. cm.; elasticity coefficient 500,000 kg. per sq. cm.; sp. gr. 2.3–2.6; sp. heat 0.2; heat conductivity 1.61 kg. cal. per sq. m. per °; porosity 2%; heat expansion (between 0° and 100°) 5×10^{-6}; hardness 7–8; solubility in acids, less than 1%. (*C. A.*)

PATENTS

Tile-fettling machine. A.W. CRISTIANI. U.S. 1,601,812, Oct. 5, 1926. A tile-fettling machine including a conveyer for a tile, a plurality of fettling members to engage the sides of a tile on conveyer, and a guide for directing the tile to fettling members,



the guide being formed to turn the tile in its own plane to present successively angularly disposed sides of the tile in the same plane to fettling members.



Pottery-finishing machine. J. L. REED. U. S. 1,602,122, Oct. 5, 1926. In a pottery finishing machine, the combination with a vertically movable rotary driving shaft and a head or wheel carried thereby and provided with friction pads, of a normally stationary work-supporting table or disk located above head or wheel, and means for lifting the shaft to bring the pads into frictional contact with table or disk to impart rotary movement thereto.

Glazing tiles. C. G. REYNOLDS, W. AND A. J. PODMORE. Eng. Pat., 250,400, Oct., 11, 1924. (See *Trans.*, **24**, 325 (1925).) (*Trans. Ceram. Soc.* [Eng.])

Porcelain insulators. BRITISH THOMPSON-HOUSTON CO. LTD. Eng. Pat., 244,965, Mar. 12, 1925.—The stem is formed with tapered seatings to fit corresponding apertures in the skirts. The parts are glazed, fitted together, and then fired. The skirts shrink on to the stem and the glaze fuses to bind the parts together.
(*Trans. Ceram. Soc.* [Eng.])

Facing material for tiles, etc. W. J. S. DUFTON, T., W. J., AND L. S. OBANK. Eng. Pat., 244,312, Mar. 27, 1925. Glazing or facing material consists of water colors, lime, or cement, or both, and pulverized linseed oil with or without infusorial earth. Slightly alkaline water should be used. (*Trans. Ceram. Soc.* [Eng.])

China body. J. E. TAMS. Eng. Pat., 242,091, Nov. 24, 1925.—The body is composed of about 10¾ parts by weight of bone, 5½ parts of china clay, and 1½ parts of hydrated magnesium silicate, or other suitable magnesium compound, all blunged together.
(*Trans. Ceram. Soc.* [Eng.])

Equipment and Apparatus

Elevator saves labor in pottery. ANON. *Ceram. Ind.*, **7** [4], 358–59 (1926).—Problem of transport from green room to kilns solved by the installation of a shelf conveyer.
F. P. H.

Recent research in fine grinding. ANON. *Rock Products*, **29** [15], 46–47 (1926).—Summary of investigations conducted by the British Portland Cement Association between 1923–25. F. P. H.

Dust arrestors and precipitators for Portland cement mills. FRANK F. STELZ. *Rock Products*, **29** [7], 58–61 (1926).—Description of methods employed in European plants. F. P. H.

The design of stone crushing plants. HUGO W. WEINER. *Rock Products*, **29** [19], 58 (1926). F. P. H.

The stream-line filter. J. W. HINCHLEY. *Chem. and Ind.*, **45**, 660–64 (1926).—The stream-line filter has reached the stage when it is becoming an important method for industrial filtration. Demonstrations were made on the filtration of clay suspensions, barium sulphate precipitated in the cold, etc., and the release of these materials as solid cake from the filter by means of compressed air. H. H. S.

Sifting plant. A. OGILVIE. *Chem. and Ind.*, **45**, 713–18 (1926).—Formerly it was considered standard practice in the reduction of materials to a fine state to hold the material in the mill until reduced to the fineness required. A departure which has been marked by increased efficiency and diminished working costs was the design of a mill which delivered a product of mixed coarseness. Oversize material is returned to the mill by screening. This "circulating system" is now the principle of several types of grinding mill. The Sturtevant (circulating) used 14 h.p. per ton per hr. in grinding hard Florida

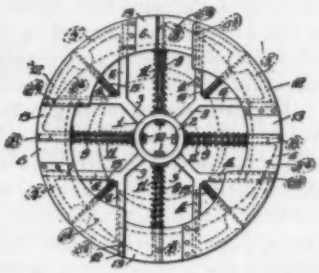
phosphate, and 3.7 per soft Gafsa phosphate, as compared to 17 and 9 respectively in a Bradley (self-contained) mill. The paper describes, with illustrations, the Newaygo, Moto-Vibro, Hummer, and Overstrom screens, and the Sturtevant and Gayco air separators. H. H. S.

New universal differential dilatometer. H. ESSER AND P. OBERHOFFER. *Stahl u. Eisen*, **46**, 142 (1926).—The construction and the method of operating a dilatometer are described, by means of which the relation between the dilatometric, magnetic, and electric properties of a material and temperature is recorded automatically. (*Trans. Ceram. Soc.* [Eng.])

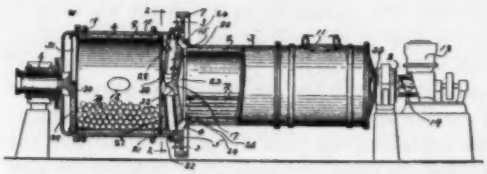
Protecting thermocouples by transparent silica tubes. R. A. RAGATZ AND O. A. HOUGEN. *Chem. Met. Eng.* **33**, 415 (1926).—Tests show that transparent silica tubes are superior to tubes of ordinary fused silica. (*C. A.*)

PATENTS

Apparatus for drying clay products. ERNEST ARGO. U. S. 1,601,711, Oct. 5, 1926. A supporting base for a molded body of plastic material comprising a series of radially disposed movable sections for the support of the molded body, the sections being free to travel with the molded body during the shrinking thereof.

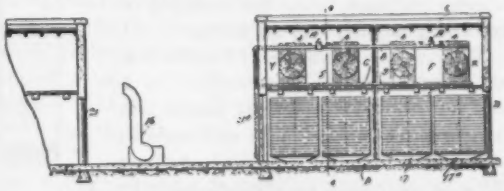


Mill. O. H. JOHNSON. U. S. 1,602,434, Oct. 12, 1926. A mill comprising a rotatable drum, shell, or barrel, reducing rods and reducing balls in the mill, the drum adjacent the discharge ends of the rods being enlarged, and a plate within the mill at the enlarged portion thereof extending transversely of the drum for preventing admixture of the rods and balls, the periphery of the plate being spaced from the wall of the drum throughout, the diameter of plate exceeding the diameter of that portion of the mill containing the rods.

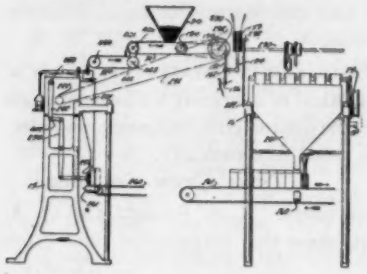


Mill. O. H. JOHNSON. U. S. 1,602,435, Oct. 12, 1926. A mill comprising a rotary drum, shell, or barrel, a sectional imperforate guard plate adjacent the discharge end of the mill, and a central plug or filler member about which the sections of the sectional guard plate are assembled.

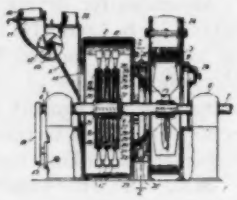
Drier. G. R. ANDERSON. U. S. 1,603,103, Oct. 12, 1926. In a drier of the character described, a housing having a drying chamber formed therein, means for heating and circulating air through the compartment, means for regulating the humidity content of the air, the means comprising an air exhausting pipe connected with the compartment, a damper in pipe, means for manually opening and closing damper, and an air inlet pipe connected with the compartment and



forming constant communication between the exterior atmosphere and the compartment, the pipe admitting fresh air to replace the air removed by the exhausting pipe and also maintaining atmospheric pressure in the drying compartment.

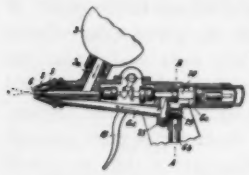


Automatic weighing machine. KARL GAMMEL. U. S. 1,603,274, Oct. 19, 1926. In an automatic weighing machine, a plurality of scale beams each having a hopper secured to one portion thereof and a pair of weights secured to a different portion thereof, to balance the scale beam when a predetermined quantity of material has been deposited in the hopper, means for depositing material into said hopper at a rapid and at a slow rate, means controlled by one of the weights actuated by a predetermined movement of the beam for discontinuing deposit of material at the rapid rate, means controlled by the other of the weights and actuated by further movement of the beam for discontinuing movement at the slow rate, and means for emptying the hoppers in a predetermined order.

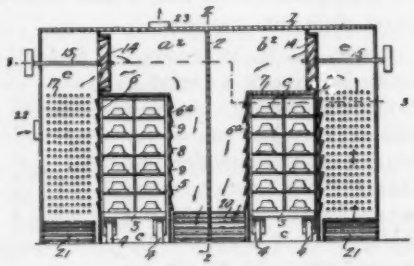


Regulator for pulverizing mills. JOE CRITES AND W. H. VOGEL. U. S. 1,603,520, Oct. 19, 1926. A pulverizing mill comprising a beater chamber having an outlet for the pulverized material, a rotary regulator mounted within the chamber adjacent the outlet, and means surrounding the regulator within the outlet and adjustable from outside the chamber for varying the effective size of the outlet with respect to the rotary regulator.

Air and color spraying apparatus. ALBERT KRAUTZBERGER. U. S. 1,603,612, Oct. 19, 1926. A color spraying apparatus, having an air valve, a color needle valve, a spindle on which the air valve is mounted, the axes of the spindle and needle valve being in line with each other, an inlet passage for the compressed air perpendicular to the line containing the axes, a valve chamber for the air valve, a pipe which is perpendicular to the line containing the axes and which leads from the valve chamber, an open communication between the pipe and the valve chamber, a member closing the end of the pipe, an air passage slightly inclined to the line containing the axes, a nozzle, the air passage lying between the nozzle and the rear end of the apparatus, an opening at the rear end of the apparatus in alinement with the air passage, a closing member in the opening whereby the air passage can be laid bare for inspection and for cleaning purposes, after the removal of the closing members, as set forth.



Drier. T. H. RHOADS. U.S.1,604,074, Oct. 19, 1926. The combination in a drier, of two drying sections placed side by side; a circulating fan for each section; a tunnel extending through both sections; trucks in the tunnel for the articles to be dried; a vertical partition having 2 openings therein, the air circulating first through one section and then through the other section, the air returning to the first section; and means



for allowing a certain proportion of the air to pass through the tunnel in direct contact with the articles being dried.

Washing clay. K. H. REICHAU. Eng. Pat., 245,608, Jan. 24, 1925. Within a water container is mounted a conduit, made up of a stepwise series of cylindrical or tapering tubular members with gaps between each member. The clay slip is admitted through a pipe to the bottom member of the series, and the washed clay is discharged through a pipe from a chamber, through the bottom of which the top member of the series projects. Means are provided for regulating the speed of the current. The coarse particles pass through the gaps between the members, and are collected from the bottom of the containers. (*Trans. Ceram. Soc.* [Eng.])

Kilns, Furnaces, Fuels, and Combustion

Oil firing of scove kilns. L. A. MEKLER. *Brick and Clay Rec.*, **69** [1], 24–25 (1926). —Discusses subject of oil burning from a practical angle. Points out factors to consider in choosing oil-burning system. A comparison of low and high pressure systems is given. F. P. H.

Oil burning with high air pressure. ANON. *Brick and Clay Rec.*, **69** [1], 26–27 (1926).—Describes the use of high pressure air at the oil burners instead of steam for atomization. F. P. H.

Reports data on oil burning tests. L. H. WILSON. *Brick and Clay Rec.*, **69** [1], 28–29 (1926).—Tests made on scove kiln fired with low pressure air show low firing cost. F. P. H.

Oil burning the country over. ANON. *Brick and Clay Rec.*, **69** [1], 30–32 (1926). —A description of oil burning equipment used at several plants over the country. F. P. H.

About producer gas. ANON. *Brick and Clay Rec.*, **69** [4], 277 (1926).—A description of a typical gas producer installation. Analyses of some coals that have been used in gas producers are given. The ratio of fixed carbon to volatile matter in a good gas coal should range from about 1.5 to 1.7. The most desirable coal should conform to following specifications: volatile matter 30 to 50%, fixed carbon 50 to 60%, ash under 15%, and ash fusing temperature, over 2200°F. F. P. H.

Excess air, friend or foe. H. C. KENYON. *Brick and Clay Rec.*, **69** [7], 502–504 (1926).—K. considers excess air a great friend of the burner. The function of excess air is to prevent the ware from over firing and to act as a heat carrying medium. F. P. H.

Protect your gas producer's heart. ANON. *Ceram. Ind.*, **7** [4], 342–43 (1926).—The blower is called the heart of the producer and failure on the part of this most important element will immediately be reflected in the quality of gas produced. The importance of the blower justifies a close check on the settings and the regular practice of checking the blast temperature will result in a gas of uniform quality. A steam flow meter can be used to measure the steam consumed by a blower or the total steam to the blowers in a producer house in which the steam of all the blowers is taken from a common steam main. As the coal gasified is proportional to the steam used, the meter, by knowing the ratio of steam to coal, can be used by interpolation as a fuel meter. Knowing the coal consumed and the steam measured gives a quick check on the blower operation. At the present time, all stress is being placed on the advantage of uniform feed in preference to the former practice of hopper feeding, and the results obtained justify the claims made for the uniform feed. F. P. H.

Electric kiln in Swedish porcelain works. ANON. *Pottery Gas.*, **51** [592], 1548–49 (1926).—A description of the electric tunnel kiln in operation at the Gustavsberg Porcelain Works. No saggers are necessary, the ware being fired on open trucks since the

atmosphere is pure. Ninety-six trucks holding about 30 cups each are fired in 8 hours with an electric current consumption of about 1¾ kilowatt hours per dozen cups.

E. J. V.

Temperature control. ANON. *Nat. Glass Budget*, **42** [23], 13 (1926); (reprinted from *Bottles*).—A short article describing and explaining the principle of the platinum-platinum rhodium thermocouple. E. J. V.

Relative value of carbon monoxide and hydrogen as constitutents of producer gas. W. E. RICE. *Glass*, **3**, 227 (1926).—Carbon monoxide is a better furnace fuel than hydrogen because of its higher calorific value, greater radiation from its flame, and higher flame temperature. Hydrogen gives a short flame and has a deleterious action on furnace walls, retorts, etc. The reasons for the greater efficiency of producer gas rich in CO are presented briefly. The producer should be so operated that (1) the fuel surface exposed is as large as possible, (2) the time of contact between fuel and gas, and (3) the temperature is as high as practicable. (*Trans. Ceram. Soc.* [Eng.])

Works experience with a tunnel kiln. O. BALLENTIN. *Keram. Rund.*, **33**, 745 (1925).—The superiority of the tunnel kiln over the round kiln is demonstrated by the following data.:

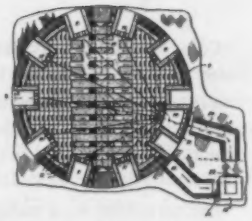
	Annular kiln (56 cu.m.) coal-fired	Tunnel kiln	
Total wt. of setting per cu. m. firing space	568 kg.	723 kg.	
Wt. of porcelain per cu. m. firing space	98.5 kg.	180 kg.	
Coal consumption per cu. m. firing space	217 kg.	117 kg.	
Coal consumption per 1 kg. setting	0.383 kg.	0.161 kg.	
Coal consumption per 1 kg. finished ware	2.2 kg.	0.64 kg.	
Cost of fuel per kg. porcelain	1	0.25	Including
Wages (firing) kg. porcelain	1	1.48	transport of
Wages (placing) kg. porcelain	1	0.12	coal, generator
Wages (emptying) kg. porcelain	1	0.35	wages, etc.
Total costs for firing 1 kg. porcelain	4	1.20	= 1 : 0.3

The costs of electric current and water comsumption and of truck repairs are not taken into consideration; they would probably increase the ratio to 1 : 0.4. The capacity of the kiln, with a firing schedule of 16 trucks per 24 hours is, 16 x 3 cu. m. = 48 cu. m. or a weekly output corresponding to 5 annular kilns of 67 cu. m. capacity. But the figures for the annular kiln include the cost of biscuit, or degourdi firing. Allowing for this, the ratio would be 1 : 0.5, or 1 : 0.6. Loss due to breakage is not more serious with a tunnel kiln than with the ordinary types; large heavy pieces are now successfully fired along with the finest domestic and art porcelain. Where excessive breakage does occur, it is usually due to careless handling of the trucks outside the kiln. The question of the best method of firing a tunnel kiln depends largely upon local conditions. Direct coal-fired tunnel kilns are still in use, but many such have been converted to gas-firing. For normal conditions generator gas is the most suitable fuel. In some cases a gas cleaning plant (dust collector, tar extractor, and scrubber) will be found advantageous. If raw gas is used a saving is effected in plant and in water and electric current consumption, but on the other hand, cleaning costs are much heavier, especially where a long and intricate system of piping leading from the generator has to be installed. It has been found in practice that porcelain can be fired with raw gas; by a proper construction and regulation of the burners, trouble due to sulphuring can be avoided.

(*Trans. Ceram. Soc.* [Eng.])

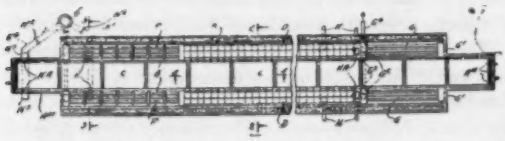
Oil firing of pottery in Russia. ANON. *Pottery Gaz.*, **51**, 235 (1926).—Porcelain is being fired satisfactorily with petroleum as fuel in a kiln which was formerly coal-fired and which has been adapted with a minimum of reconstruction. The quality of the porcelain is satisfactory. (*Trans. Ceram. Soc.* [Eng.])

PATENTS

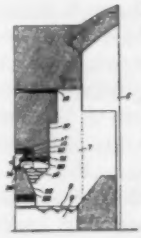


Downdraft kiln and method of operating the same. P. J. LENGSHOLZ. U. S. 1,601,028, Sept. 28, 1926. The method of kiln firing a charge of clay products, which consists in alternately directing a substantial cross draft and a down draft through the charge.

Tunnel kiln. L. A. VINCENT. U. S. 1,601,748, Oct. 5, 1926. In a continuous tunnel kiln provided with closed combustion chambers at the sides of the goods pathway through the kiln, from which heat is transferred to the ware passing through the kiln mainly by a transverse convection circulation of the kiln atmosphere, the improvement which consists in means for exerting a kiln atmosphere exhausting effect at the ware entrance end of the kiln adjacent the bottom level of the goods pathway therethrough.



Tunnel kiln. H. R. STRAIGHT. U. S. 1,602,721, Oct. 12, 1926. In a tunnel kiln for firing ceramic ware, means for supporting and moving ware to be fired through said kiln comprising a heating zone, a maximum temperature zone, and a cooling zone, the heating zone and the cooling zone each being provided in a series of intermediate sections, means for introducing a cooling medium along the sides of the ware in one of the cooling sections, then horizontally beneath the bottom of the ware and upwardly through it, thence downwardly past the sides of the ware in the second section of the cooling zone, thence upwardly and again through the ware, thence downwardly through the ware in the maximum temperature zone, thence upwardly past the side to the top in one of the sections of heating zone, thence downwardly through the ware in section, thence horizontally, outwardly, longitudinally, and upwardly along the side of the ware to the top of the ware in the second section of the heating zone and downwardly and outwardly as described.



Brick kiln furnace. J. H. WARWOOD. U. S. 1,604,005, Oct. 19, 1926. A brick kiln furnace comprising a front wall having a substantially semicircular opening therein and having lateral damper-controlled passages communicating with opposite sides of the opening at low points thereof, and a substantially semicircular front frame mounted in the opening and having inner and outer walls for enclosing a preheating chamber for the air, the outer wall having cut away parts at its ends to register with the air passages in the furnace wall, the inner frame wall having a central slot for directing the air downwardly into the combustion chamber of the furnace.

Tunnel kiln. H. T. PADELT. Eng. Pat., 245,005, June 16, 1925. Four groups of mixing chambers and burners are arranged side by side and one above another.

(*Trans. Ceram. Soc.* [Eng.])

Automatic furnace charges. C. CEBULLA. Eng. Pat., 250,505, Jan. 4, 1926. The apparatus consists of a hopper fitted with a feed roller, above which are arranged spaced rollers which rotate in the same direction at different speeds.

(*Trans. Ceram. Soc.* [Eng.])

Geology

Colors produced by iron in minerals and the sediments. G. R. MacCarthy. *Amer. Jour. Sci.*, **12**, 17–36 (1926).—The influence of the ferro-ferric ratio on color is discussed. As this ratio increases from .447 to 23.0 there appears to be a somewhat regular transition from the reds and yellows of the almost purely ferric substances through the greens and blues of the intermediate groups to the prevailing blacks of the almost purely ferrous materials. F. P. H.

Dumortierite as a commercial mineral. A. B. Peck. *Amer. Mineral.*, **11** [4], 96 (1926).—Location of the Champion mine in Nevada operated by the Champion Porcelain Co. and occurrence of the mineral dumortierite at this mine are described. The rock as mined is composed of very minute prismatic needles of dumortierite very intimately intergrown with muscovite. The mineral on firing breaks down at a low temperature, beginning at cone 10 or a little lower. The result of this dissocation is the formation of a very intimate mixture of mullite crystals in glass. When the breakdown first occurs there is no definite orientation of the mullite crystals with reference to the original dumortierite grains. When the rock is fired it expands as it dissociates and changes in color to a pure white and takes on a dull porcelain-like luster. Test cones formed from the powdered rock fuse sharply at 1810°C. F. P. H.

Georgia rich in clays. Anon. *The Clay-Worker*, **86** [3], 221 (1926).—Nearly every type of clay is found in Georgia is the claim of the Atlanta Chamber of Commerce. F. P. H.

How kaolin is prepared for use by Florida producers. J. R. Thoenen. *Rock Products*, **29** [17], 38–39 (1926). F. P. H.

Fullers' earth. H. Gunther. *Mineral Ind.*, **33**, 264–65 (1924).—Fullers' earth is a clay differing from other clays in that it has to an unusual degree the quality of absorbing coloring matters from oils and some other liquids. In appearance it is frequently difficult to distinguish from other clays, the final criterion being its power of removing coloring matter from oils in filtration. T. N. Mc V.

The International Geological Congress at Madrid. Anon. *Nature*, **118**, 234 (1926).—The fourteenth congress was held at Madrid under the presidency of Rubio, head of the Dept. of Mines of Spain. Papers included the study of the configuration and economic possibilities of rocks by electric, magnetic, and gravimetric methods. Progress was reported on the international geological map of Africa, resolved at the previous congress at Brussels in 1922. Excursions included the Hg mines of Almeden, the potash deposits of Catalonia, the coal field of the Asturias, the iron ores of Bilbao, and others further afield to the Canary Islands and Morocco. H. H. S.

Kaolin. Sabie, South Africa. W. J. Wybergh. Union of South Africa, *Geol. Surv. Mem.*, **23**, 43–44 (1925).—An extensive deposit of remarkably pure white kaolin has been located near Sabie. It is not improbable that other similar deposits exist in this district. O. P. R. O.

Clays. Anon. N. Z. Dept. Mines, *Mineral Deposits*, 14–15 (1925).—Clays occur in numerous localities and in many varieties. Brick, drain-pipe, and roofing-tile industries are established in N. Z. Clays suitable for pottery-ware and china occur in several localities, but little is known of the extent of these beds. O. P. R. O.

Clays. Anon. Dept. of Mines and Geology, *Clays*, [7], 9 p., n. d.—Clays occur in many localities in the Gwalior State; their chemical compositions and physical properties approach to a great extent those mentioned by Fernival, the famous English authority on the manufacture of faience, as typical clays for salt and glazed wares. O. P. R. O.

Chemistry and Physics

Future progress in ceramic chemistry. GEORGE W. MOREY. *Ind. Eng. Chem.*, **18** [10], 1023–25 (1926).—The possibilities for continued progress with the recently acquired knowledge as a starting point in the following fields are discussed and suggested: cement, refractories, glass, and silicate chemistry. E. J. V.

Aluminate of lead. ANON. *Chemical Trade Jour. and Chem. Eng.*, **79**, 309 (1926).—A possible new white pigment. The successful preparation of lead aluminate is announced by B. Garre, of Danzig, in Sept. 4, 1926, issue of *Chemiker-Zeitung*. Hitherto attempts at preparing this substance have proved fruitless, for if a molecular mixture of litharge and alumina is heated, the litharge commences to melt at about 879°C and to volatilize at a temperature as low as 900°C. Aluminium oxide itself does not melt below a temperature of 2010°C and consequently the bulk of the litharge has been lost before conditions conducive to chemical reaction have been reached. If the heating be conducted in a reducing atmosphere the litharge is largely converted to metallic lead. G. has succeeded in producing lead aluminate by mixing litharge and alumina in molecular proportions, and subjecting the mixture, in the form of small granules, to a temperature of 700°C for a long period. The mixture is originally yellowish in color, but as the heating proceeds the color changes to a pure white. No melting takes place, the mixture retaining its solid form throughout. The reaction slows up with time, due to the formation of a layer of aluminite between the adjacent particles of litharge and alumina. The product finally obtained is a pure white powder of the composition $PbO \cdot Al_2O_3$. Its covering power is equal to that of white lead. *Lead Aluminate-Silicate.* Pure alumina is not essential in the production of lead aluminate; iron-free clay can be employed, but in addition to the lead aluminate, white lead silicate is also formed and an excess of litharge should therefore be used. It has been found that a lead aluminate–silica mixture formed by the decomposition of a lead-aluminate–lead silicate mixture with dilute mineral acids, possesses excellent pigment properties of its own. O. P. R. O.

The chemical family of glazes. E. ZSCHIMMER. *Keramos*, **4**, 23 (1925).—Every glaze, however compounded, represents one point in the field of unlimited possibilities obtained by varying the proportions of the ingredients of the glass oxides. Examples are taken from the list of glazes given by Hecht in his "Lehrbuch der Keramik" to illustrate this point. (*Trans. Ceram. Soc.* [Eng.])

Practical experience with the rational analysis of kaolins. G. KOPKA AND F. ZAPP. *Keramos*, **5**, 183 (1926).—The following methods were investigated: Berdel, Bollenbach, Kallauner, Kallauner-Matejka, Schwalbe, and Schmidt. Special attention was devoted to the Kallauner-Matejka method. The most suitable fusing temperature was between 740 and 760°; it should not exceed 800°. Fusion should not be continued longer than 2 hrs. The equation: Loss on ignition +alumina (incl. Fe_2O_3)+HCl = insoluble = 100, is convenient as a control of the Kallauner analysis. It is concluded that rational analysis cannot be regarded in any sense as an exact chemical procedure. The Kallauner method is given preference over other methods tried. (*Trans. Ceram. Soc.* [Eng.])

Water-glass manufacture. R. DECKERT. *Chem. Ztg.*, **50**, 535–36 (1926).—Water-glass is made in tank furnaces with regenerative heating. The most suitable temperature is 1300–1400°. Wear and tear on a furnace are very great. Raw materials (sand, Glauber salt, and soda) must be dry and powdered. To prepare a solution from the water glass a revolving drum is charged to about one-third its volume with the solid, water is then added until the drum is ¾ full, and the mass extracted hot under a pressure of 5–6 atmospheres for 3–4 hrs. The solution is filtered after decantation. Any color in the solution is ordinarily due to organic impurities taken up during storage of the

product; these can be removed by a preliminary washing of the solid water-glass. Animal charcoal is also used for clarifying the resultant solution, 500 g. of it purifying 10,000 kg. of water-glass solution of 36–38° Bé. For export trade the solution is evaporated *in vacuo* to sp. gr. 58–60° Bé. The weaker solution contains about 27% SiO_2 and 8% Na_2O, and the stronger, 37% SiO_2 and 18% Na_2O; the additional Na_2O is added in very concentrated solution just before evaporation. (*C. A.*)

X-ray researches on aluminum silicates. P. Rosbaud. *Z Elektrochem.*, **32**, 317–19 (1926).—The results in cell dimensions, space-group and number of molecules per unit are as follows: disthene, $Al_2O_3.SiO_2$, 7.18×8.00×5.55 A. U.; C (triclinic pinacoidal); 4 mols.; andalusite, $Al_2O_3.SiO_2$, 7.90×7.90×5.50 A. U.; V_h^{12}, 4 mols.; sillimanite, $Al_2O_3.SiO_2$, 7.25×7.65×5.88 A. U.; V_h^{16}; 4 mols.; mullite, 3 $Al_2O_3.2\ SiO_2$, 7.25×7.65 ×2.94 A. U.; V_2^9; 2 mols.; pseudobrookite, Fe_2TiO_5, 9.78×9.80×3.65 A. U.; V_h^{12}; 4 mols. The marked similarity between sillimanite and mullite is particularly noted. It is maintained that the cryst. phase of mullite is not $3Al_2O_3.2SiO_2$ but $Al_2O_3.SiO_2$. (*C. A.*)

The use of the microscope in the glass and ceramic industries. Hans Schulz. *Mikrokosmos*, **19**, 217–20 (1925–26).—The methods of preparing thin sections and of converting a biological microscope into one for petrographic study are given. Microscopy aids in the determination of the conditions of preparation and heating of ceramic materials. In small glass batches heated for 8 hrs. it was found that 20.5 and 34.5% were the highest contents of CaO and BaO, respectively, which could be contained without devitrification. (*C. A.*)

The structure of Carborundum. III. The third modification and the amorphous carbide. H. Ott. *Z. Krist.*, **63**, 1–18 (1926).—A detailed account of the structure of the third type of Carborundum. The so-called *amorphous carbide* consists of a mixture of type II with material which possessed the diamond type of structure. All 4 modifications have in common the arrangement whereby each atom of one kind is surrounded by 4 atoms of the other kind. (*C. A.*)

The nature of stannic acids. E. Posnjak. *Jour. Phys. Chem.*, **30**, 1073–77 (1926). —The Röntgen-ray picture of powders of so-called α- and β-stannic acids shows that they are identical and essentially SnO_2 but that the β-form has coarser particles. A discussion of the later literature on this subject is given and a table of the experimental data. (*C. A.*)

A method for measuring refractive indexes under the microscope. Kinzo Nakashima. *Jour. Geology*, **34**, 235–47 (1926).—The principle of the Abbé refractometer is applied to a petrographic microscope, and the *ns* of minerals are determined by using the Fedorov stage. (*C. A.*)

The action of silica on electrolytes. A. F. Joseph. *Nature*, **117**, 17 (1926).—A test on carefully prepared SiO_2 dried at air temperature did not show the absorbing power for HCl claimed by Mukerjee. (*C. A.*)

Researches on silicates. III. Hydrolysis of sodium silicates. Gunner Hägg. *Z. anorg. allgem. Chem.*, **155**, 21–41 (1926).—Potentiometric determinations of the degree of hydrolysis of various Na_2O:SiO_2 mixtures were made at 20° with careful exclusion of CO_2. Values for the recrystallized metasilicate and for synthetic metasilicate prepared by fusion from the components, were the same (50% hydrolysis); for metasilicate by dissolution of SiO_2 in NaOH the value was 42%; the CO_2 could not be excluded entirely. Tabulated values of hydrolysis (figured on total Na_2O) are given for dilutions varying from 2 to 512 l. per molecule Na_2O and ratios Na_2O:SiO_2 of 2 to $\frac{1}{4}$; all these values are slightly low on account of CO_2. If it is assumed that the CO_2 contamination is proportional to the OH-ion concentration, the limiting value for hydrolysis can be calculated for a ratio Na_2O:SiO_2 of 2 to be 0.75; for ratio 1 to be 0.50; for

ratio $\frac{1}{3}$ to be 0.25 No constant values for the first dissociation constant k_1 of H_2SiO_3 could be found; it is of the order 10^{-9}, if the presence of $HSiO_3$ ions alone and no colloidal deposition of H_2SiO_3 is assumed. The constant k of the hydrolysis reaction $SiO_3^{--} + H_2O = OH^- + HSiO_3^-$ sinks rapidly up to $v = 125$, remains constant as far as $v = 250$ and then drops again. The constant value 0.04 corresponds to a second dissociation constant k_2 of H_2SiO_3 of the order 10^{-13} on the assumption that there is no colloidal H_2SiO_3. In silicate solutions of $\frac{1}{3}$ ratio, part of the silicic acid is in colloidal solution; this makes the hydrolysis curve convex towards the dilution axis because of adsorption of OH ions. Cryoscopic measurements on the same set of Na silicate solutions were made to decide about the presence of SiO_2 in colloidal form. In the 1 : 1 ratio solutions measured values, agreeing with the theory, proved the absence of colloids, and in the 2 : 3 solutions, the absence of appreciable amounts, it appears that the $HSiO_3^-$ ions do not form colloids; no decision could be made about the H_2SiO_3 itself. (*C. A.*)

Study of the production of pure aluminum in the aluminum industry from insoluble aluminous materials such as clay or alunite. JINGORO YAMAZAKI. *Jour. Soc. Chem. Ind.* (Japan), **29**, 154–60 (1926).—The raw materials used are Japanese clay and Korean alunite. By ignition they become easily soluble in H_2SO_4. The ignition temperature is 700–800° for the clay and 550° for the alunite. Over 95% of Al_2O_3 is dissolved in H_2SO_4 of 50.9° Bé. The clear solution thus obtained contains $Al_2(SO_4)_3$, $Fe_2(SO_4)_3$, etc. When sufficient $(NH_4)_2SO_4$ is added to convert all the Al to alum and the solution is crystallized, Fe remains in solution. By the direct action of dry NH_3, at 75°, the crystal alum gives $Al(OH)_3$ and $(NH_4)_2SO_4$; the $Al(OH)_3$ thus prepared is in compact granular particles, is easily filterable and washable and becomes pure by H_2O extraction. A comparison between Al hydroxide (molecular formula: $Al_2O_3.2H_2O$) obtained as above and the one prepared by the Bayer process shows that the two have almost the same volume. By drying and igniting, alumina of the following composition is obtained: 99.3% Al_2O_3, 0.111% Fe_2O_3, 0.104% SiO_2, CaO and MgO trace and 0.4% H_2O. From this, metallic Al of the following composition is produced: 98.90% Al, 0.76% Si and 0.15 % Fe. The experiment was conducted on the semi-works scale. The production cost of the Al_2O_3 on this scale is Y 121.90 per ton and that of Al using the Al_2O_3 is Y 843.33 per ton. (*C. A.*)

Production of alumina from alunite. JINGORO YAMAZAKI AND JINROKU FURUKAWA. *Jour. Soc. Chem. Ind.* (Japan), **29**, 147–53 (1926).—Pure alumina (99.65% Al_2O_3, 0.09% Fe_2O_3 and 0.24% SiO_2) is prepared from alunite ($K_2O.3Al_2O_3.4SO_3.6H_2O$) by H_2SO_3 treatment. One part of alunite, ignited at 550° for 3 hrs. and powdered, is mixed with 10 parts of H_2O and SO_2 is introduced at 65°; more than 90% of the alunite is dissolved. The clear solution thus obtained contains $Al_2(SO_4)_3$, K_2SO_4 and $Al_2(SO_3)_3$. When it is heated to 110°, SO_2 is evolved. In the early stages of the heating $5Al_2O_3.3SO_3.15H_2O$ is precipitated, but after long heating all the Al in the solution is precipitated as $5Al_2O_3.3SO_3.2[K_2SO_4.Al(SO_4)_3]24H_2O$; the separation of Al and K is therefore impossible. By adding an equivalent amount of $(NH_4)_2SO_3$ or $CaSO_3$ to $Al_2(SO_3)_3$ in the above solution and heating at 110°, over 94% of Al_2O_3 is precipitated as $5Al_2O_3.3SO_3.15H_2O$ in an easily filterable form; $(NH_4)_2SO_4$ and K_2SO_4 are obtained from the solution. After drying, the basic Al compound thus obtained is heated at above 900°, pure Al_2O_3 is then produced with the evolution of SO_2. By dissolving the $5Al_2O_3.3SO_3.15H_2O$ in H_2SO_4, pure $Al_2(SO_4)_3$ is produced, which contains almost no Fe and is used in *paper manuf.* (*C. A.*)

Structure of beryl, $Be_3Al_2Si_6O_{18}$. W. L. BRAGG AND J. WEST. *Proc. Roy. Soc.* (London), **111A**, 691–714 (1926).—By a remarkable use of X-ray intensity data and the Duane-Fourier series method, the unique structure of beryl involving 7 parameters is derived. The hexagonal crystal has the values $c = 9.17$ and $a = 9.21$ A. U. with 2 mole-

cules per unit cell and space group D_{6h}^2. Every Si alone is surrounded tetrahedrally by 4 O atoms, every Al octahedrally by 6 O and every Be atom by 4 O atoms on a distorted tetrahedron. Si and O atoms form rings of the composition Si_6O_{18}. These rings have a hexagonal axis and equatorial plane of symmetry and are arranged around the hexagonal axis. They are composed of SiO_4 groups, each group being joined to its neighbor on either side in the ring by an O atom held in common. The rings are stacked on each other along the hexagonal axes, forming a series of open channels, for no atomic center is nearer than 2.55 A. U. to a hexagonal axis. The rings are linked together by the Al and Be atoms. The whole structure is like a honey comb with the hexagonal axes passing down the centers of the cells and with walls formed of closely packed O atoms. (*C. A.*)

Can the study of devitrification lead to technological knowledge? H. HERMANN. *Sprechsaal*, **59**, 142 (1926).—It was possible by studying the products of devitrification to obtain information as to the temperature conditions of the furnace. As an example, β-wollastonite had an inversion temperature of 1210°, a temperature exceeding that at which such crystals were formed in a pure silicate melt. Conclusions of this kind could only be drawn, however, when no oxides were present which affected the inversion point by the formation of mixed crystals. The common form of silica crystallization in tank furnaces was cristobalite, indicating probably incomplete fining. Indeed, it was likely that the free silica in the glass consisted partly of cristobalite and partly of tridymite, the proportions of each present affecting the physical properties of the glass. Since cullet and saltcake glasses differed from batch glasses, it was suggested that these materials acted as catalysts speeding up the conversion of cristobalite to tridymite. Many cases of devitrification could not be explained by means of the ternary diagram, since they were caused by chemical inhomogeneity of the system. It was possible to form some idea of the relative variations from the ideal analysis in some cases. For instance, a glass of the percentage composition, as analyzed, Na_2O 16.3, CaO 10.2, SiO_2 73.5 gave cristobalite crystals. Since the diagram indicated that the field with silica as primary phase began at 76% silica, there must have been a variation of at least 2.5% in the silica content from the ideal analysis. In H's view, it was incorrect and misleading to speak of the devitrification furtherance or retardation of individual oxides.

(*Jour. Soc. Glass Tech. Abs.*)

The heat capacities of some metallic oxides. G. S. PARKS AND K. K. KELLEY. *Jour. Phys. Chem.*, **30**, 47 (1926).—The heat capacities of the oxides of magnesium, calcium, aluminium, and iron were determined over the range 90–300° Abs. The following are typical results abstracted from the tables: MgO : Cp = 0.2096 per gm. at 2.3° and 0.2184 per gm. at 18°. CaO : Cp = 0.1762 per gm. at 2.4°, 0.1808 per gm. at 19.7°. Al_2O_3: Cp = 0.1726 per gm. at 2.1°, 0.1813 at 18.3°. Fe_2O_3 : Cp = 0.1521 per gm. at 1.9°. Fe_3O_4 : Cp = 0.1513 per gm. at 3.3°. (*Jour. Soc. Glass Tech. Abs.*)

PATENTS

Flux for enamel, glass, and ceramic materials. HENRY BLUMENBERG, JR. U. S. 1,601,231, Sept. 28, 1926. A flux for enamel, glass, or ceramic compositions containing boron phosphate.

Flux for enamel compositions. HENRY BLUMENBERG, JR. U. S. 1,601,232, Sept. 28, 1926. A flux for enamel, glass, or ceramic compound containing alkali metal boron phosphate.

General

The type of research for government and university laboratories. A. V. BLEININGER. *Bull. Amer. Ceram. Soc.*, 5 [10], 386–90 (1926).—The general meaning of the word research is discussed. The need for fundamental knowledge is stressed and the

proposition is advanced that researches carried on in government laboratories should be of a scientific rather than economic and factory character. A tentative program of fundamental researches to be carried out is advanced and discussed. E. J. V.

Some of the less obvious aspects of ceramic education. A. E. MacGee. *Bull. Amer. Ceram. Soc.*, **5** [10], 390–96 (1926).—Aspects of ceramic education which are not included in ceramic courses are enumerated and discussed. These include human engineering, ability to speak, business management, mathematics, foreign languages, mechanics and heat, chemistry, analysis of industries, cements, glass and abrasives, time required, graduate work, and thesis requirement. The need for a standardization of courses in various schools is also brought out. E. J. V.

Benefits of a coördinated program of ceramic investigations by federal, state, and university agencies. W. K. McAfee. *Bull. Amer. Ceram. Soc.*, **5** [10], 396–99 (1926).—Ceramic technology's rapid development gives much impetus to ceramic research. The rate of progress will depend upon the care used to lay out a comprehensive program and the maintenance of coördination between federal, state, and university agencies. The types of research which should be conducted by the various investigating agencies are generally set forth. E. J. V.

Technical classes in pottery and glass. Anon. *Pottery Gaz.*, **51** [592], 1549–51 (1926).—A continuation of the list of schools and courses offered by them in ceramics. See also *Ceram. Abs.* **5** [11], 377 (1926). E. J. V.

Fifty years' progress in the pottery and glass trade. VIII. Anon. *Pottery Gaz.*, **51** [592], 1560–62 (1926).—A historical sketch of ceramic plants in Hanley, England, and their development in the past 50 years. E. J. V.

Pottery and glass trade in Sweden. Anon. *Pottery Gaz.*, **51** [592], 1565 (1926).—The particular types of articles in greatest demand in Sweden are listed and the inability of Swedish manufacturers to meet the demand is stressed. E. J. V.

The influence of chemistry on ceramics. Ross C. Purdy. *Pottery Gaz.*, **51** [592], 1574 (1926); reprinted from *Ind. Eng. Chem.*, **18** [9], 952–53 (1926); see also *Ceram. Abs.*, **5** [11], 378 (1926). E. J. V.

Oil engines as power cost reducers. Anon. *Brick and Clay Rec.*, **69** [1], 20–23 (1926).—A discussion of advantages of Diesel power. Operating cost of a Diesel engine plant is compared with a modern steam power plant. Distribution of power costs in a typical Diesel engine power plant is given. F. P. H.

The progress of research work. Anon. *Brick and Clay Rec.*, **69** [6], 439 (1926).—A brief résumé of the work of the Bureau of Standards. F. P H.

Philadelphia entertains American Ceramic Society at Summer Meeting. Anon. *Ceram. Ind.*, **7** [4], 374–76 (1926).—A paper by A. V. Bleininger entitled, "What are the Fundamentals of Ceramic Materials, Mixtures, and Wares Which Should be Investigated by Federal Bureaus?" was read. Prof. Bleininger makes a strong plea for the study of fundamentals. A paper by W. K. McAfee discussing "Benefits of a Coördinated Program of Ceramic Investigations by Federal, State, and University Laboratories," was read. McA. would have closer coördination of all research agencies engaged in ceramic work. Secretary Ross C. Purdy spoke on the proposed American Ceramic Research Institute. F. H. Rhead presented a paper on "The Need of Education and Research Combining Substance, Form, and Decoration of Ceramic Ware." Abstracts of these papers are given. F. P. H.

Psycho-technique in the ceramic industry. A. Zoellner. *Keramos*, **4**, 11 (1925).—The possibility of introducing psycho-technical vocational tests in the ceramic industry was studied. The vocational test, as applied to apprentices and youthful employees, consists of a general preliminary test, and various special tests. The object of the preliminary test is to effect a rough classification of the young people according to their

physical fitness, scholarship, efficiency of the sensory organs, intelligence, and powers of perception. The result of the first test must not be considered conclusive; on the contrary, the test should be repeated at suitable intervals. The preliminary test includes: (1) the medical examination for general health and physical fitness; (2) registrationin a special card index of personal details, *e.g.*, age, occupation of parents, distance from house to works, general behavior, cleanliness, etc.; (3) tests in elementary school subjects, such as handwriting, spelling and composition, arithmetic, etc., (4) the true psycho-technical test, which includes testing the health and efficiency of the sensory organs, and the intelligence. It is carried out by the aid of suitable apparatus for determining the strength of the eyesight and hearing, and of the sense of touch, and for testing for color-blindness, and for nervous reactions (reflexes). The test supplies information on the subject's power of observation, or attentiveness, his will power, physical and mental capabilities, skill, carefulness, endurance, and his powers of concentrated effort. The results of all these tests should be entered in the card index. After having passed the preliminary trials, the apprentices should be put to special tests according to the type of work for which they appear most suited. (*Trans. Ceram. Soc.* [Eng.])

Recent research in the science of fine grinding done by the British Portland Cement Research Association between 1923 and 1925. GEOFFREY MARTIN. *Jour. Soc. Chem. Ind.*, **45**, 160–63T (1926).—The results of grinding quartz sand are summarized in 4 laws: (1) The surface produced is proportional to the work done. (2) The number of particles produced increases with decreasing diameter according to the law of compound interest. (3) The average shape of the particles remains unaffected by crushing. (4) Any grade of crushed sand is composed of homogeneous grades in which the distribution of the numbers of the particles with their diameters cannot be altered no matter how often the sand is regraded. A consideration of the thermodynamics connected with grinding hard substances is given and the significance of the laws formulated above is discussed. (*C. A.*)

Some uses of quartz and silica products in industry. J. STEWART REMINGTON. *Ind. Chemist*, **2**, 347–50 (1926). (*C. A.*)

PATENT

Purifying clay. O. LIETZENMAYER. Eng. Pat., 248,639, Aug. 17, 1925. Clay is made into a paste with enough acid to combine with the impurities; the paste is then dried sufficiently to render the impurities soluble in water, and finally leached with water. The purified sludge is dried and ground. (*Trans. Ceram. Soc.* [Eng.])

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RESEARCH AND EDUCATION

Special Topics for Conference at Annual Meeting, AMERICAN CERAMIC SOCIETY, February 14–19, Detroit.

The Committee on Research will have a symposium on the question of benefits of a National Ceramic Research Council.

The Committee on Education will have symposiums on (*a*) ceramic curricula for engineers, technologists, and artists, (*b*) university extension, and (*c*) closer collaboration of universities and industries.

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EDITORIAL

TOO MANY CERAMIC SCHOOLS?

The flat statement has been made that the money used for ceramic departments in most of the schools could more profitably be otherwise used.

Some have stated that since the adaptibility of the school graduate depends most largely on his natural talents including initiative, specialization should be minimized if not entirely eliminated.

Statements of this kind are made we fear without appreciation of the facts. We shall contend that a ceramic school could return profits to the tax payers in each of the states where the amount of ceramic manufacturing, active and potential, is an appreciable factor in the state's economic welfare.

It is true that a large percentage of the technical men who are successful in any one of the ceramic industries have not been trained in ceramic schools. In some of the ceramic industries the majority of the technical men are not school trained ceramists. It is not unusual for the personnel of a committee or a local section meeting of this Society to be more than 75% non-ceramic school graduates. These facts together with the fact that no capable ceramic graduate is without a position and that the demand for ceramic graduates is greater than the supply should be accepted as evidence that the potential employment possibilities for graduates of ceramic schools are greater than has

been supposed. It is no disparagement to the chemist employed in ceramics to say that when graduates of ceramic schools are equipped to serve the glass and enamel industries as well as these industries are now being served by chemists the future technical development in glass and enamel will be greatly enhanced.

We are of the opinion that the criticism of the number of ceramic schools is misplaced; it should be on the character of the instruction and on the character of service rendered by the ceramic schools to the ceramic industries in their respective states.

Specialization in collegiate instruction has proved sound in principle and positive in results. The fact that an industry is established on a sound financial basis and with an excellent product long before there are special courses in colleges to train men for service in them is natural. Industries developing a need for especially trained men is the cause and the special courses in colleges are the results.

The first engineering school in America was established at Rensselaer Polytechnic Institute in 1824. Prior to that date American flour and textile mills, the cotton gin, and several other manufacturing industries were operating with steam power and rapidly improving machinery. Steam ships were navigating rivers and seas, and steam engines were hauling passengers and freight on rails long before the Rensselaer engineering school was opened.

Twenty-three years later (1847) the Lawrence Scientific School at Harvard and the Sheffield School at Yale were started. Except for a course in civil engineering at the University of Michigan these three were the only schools prior to the civil war with special engineering courses.

The Morrill act in 1862 by which land grant endowments were made to state universities for the maintenance of instruction in the agricultural and mechanical arts was in response to the dire need for men especially trained in agriculture and in the mechanical arts. Now there are 130 engineering schools of college grade in the United States.

Special courses are always in response to demands of established industries. Industries can develop to a high degree without especially trained men but competitive large scale production at low unit cost and improved product requires constant development and strict control of process and product which are possible only with especially trained technologists and engineers.

When a country needs industrial development as did America in 1862; when States (as have ten of the forty-eight) come to know that their ceramic industries are essentials; when individual ceramic concerns realize that self-maintenance in industrial competition depends

on improved production and product, then and not till then will they train persons intensively to develop, produce, and improve.

Chemists and general science investigators were available but only rarely employed in ceramics until after ceramic schools and their graduates pointed out problems and their possible solution. Today ceramics industrially and scientifically is being greatly advanced by men trained in general science, and the contributions in service rendered and in facts proved by pure science will increase in amount with each passing year. This record of achievement in ceramics by the fundamental scientists should argue for more rather than for less specialization in ceramics. Increasing service and increasing need in ceramics for service by the fundamental scientist and by the especially trained ceramist will keep apace.

We have previously stressed the need of 100% engineering courses for the training of ceramic engineers; of science, art, and technology courses for the training of ceramic technologists; for advance courses in science applied to ceramics for the training of ceramic scientists, and for art courses for the training of ceramic artists. Stress has also been given to the need of training students to think in terms of and do research on product rather than on abstract problems unrelated to products for specific purposes.

Ceramic schools will justify their existence when they evidence progress in form and substance of the lecture and laboratory courses over that of twenty and thirty years ago.

Evidently the students do profit from the empirical laboratory trials which rehearse the limits of possible material combinations for glazes and bodies of a general character. It would be idle to argue against the evidenced possession of serviceability and knowledge by the recent ceramic graduates. It is not idle but very much to the point, however, to say that our ceramic graduates are trained neither as engineers nor as technologists as their employers have a right to expect.

Some one has said that it is not necessary for each member of a civilization to recapitulate the experiences of each member of the race, and a race is civilized only insofar as the necessity for recapitulation is obviated.

Progress in ceramics cannot be made by continually covering in class and laboratory the same ground over which the students of three decades past had to work because of a lack of recorded information. The instructor who does not start his pupils with the recorded information and progress on to new conceptions of the use of known data is retarding ceramic "civilization." So long as our ceramic schools continue to trace over recorded history those who are trained in the general sciences will have the advantage over the ceramic technologists and

the broadly trained engineer will have advantage over the ceramic engineers.

Schools can render service to their respective states by uniting the ceramic manufacturers in support of ceramic research and education. The varied facilities of the state universities are available provided they are intelligently directed to the solution of ceramic problems. Ceramic manufacturers in most states have not had their just share of benefits from the universities largely because they have not known how to obtain these research and instructional benefits. It would advance the ceramic schools and the ceramic instructors in the esteem of their constituents and of the ceramic workers generally if the possible means for research and instruction financed by the state were worked out with their state ceramic associations.

Collaboration on raw material development and conservation, on plant economies, on new developments in product and processes, and on several other projects by which the ceramic manufacturers of the state can hold their own in competition is one of the largest benefits which a ceramic school in a given state can render to their state constituents and to the country at large.

The value of any or all ceramic schools depends altogether upon the instructors and the state ceramic associations. We cannot have too many ceramic schools provided the schools serve their constituents in the many ways, the value and efficacy of which have been demonstrated by other organized groups working with and for their specialized department in the university.

Ceramic Education

There is an extremely helpful and interesting discussion now going on by letter between the members of the Educational Committee, the directors of the ceramic schools, and some of the officers of the SOCIETY. It is desired that more members of the industry discuss the problem of ceramic education from the point of view of the manufacturer. If you have any criticism or recommendation, either for or against the present methods of ceramic education, please set them down in a letter addressed to Ross C. Purdy, General Secretary, at his office in Columbus. Copies will be made of your letter and forwarded to those entering into the discussion.

We are particularly interested in criticism of the sample curricula set forth in the editorial in the November issue of the *Bulletin*.

W. K. MCAFEE, Chairman
Cambridge Sanitary Mfg. Co.
Cambridge, Ohio

PAPERS AND DISCUSSIONS

SAGGER SYMPOSIUM[1]

LED BY A. V. BLEININGER

Last year, there were reported to this Division by the Bureau of Standards the results of tests of the physical properties of sagger clays, from which we were able to group this entire number (some fifty sagger clays) into five groups; and the physical characteristics of those groups are given in a paper published in the *Journal* for March, 1926, pages 131–43. Having determined the physical characteristics, and having found a reasonable basis upon which to group clays, we propose to continue a somewhat intensive study of each group, the idea being that we should study the best combination of clays, etc. The first step in the intensive study was the determination of the thermal expansion characteristics of the various clays, and the work for the past year has been confined practically entirely to the development of apparatus for determining the coefficient of expansion and the determination of several expansion curves. It is only a progress report. You probably do not want to spend too much time in describing the machine itself. At the same time, the apparatus is such as can be made in the average laboratory.

Determination of thermal expansion is a criterion for the judging of sagger clays and sagger mixtures, and we have realized that this is a factor, and the need of greater work along this line is brought out by this paper.

W. H. VAUGHN: We have investigated the coefficient of expansion in a recording apparatus on a group of sagger mixtures, including some standard sagger mixtures by various white ware companies. The sagger mixtures having a porosity above 25% have a very decided expansion between 95 and 205°C. I have figured roughly a coefficient of expansion between 20 and 700°, and a coefficient of expansion between 95 and 205°C and found that between 60 and 180°, the coefficient is about three times that between 22 and 700°. Two standard mixtures did not give such a decided expansion between 95 and 205°, although they had a greater expansion between 20 and 700°C.

A. V. BLEININGER: Will you tell us what you have noticed in cooling a kiln, or what effect, faster or slower cooling has on the saggers? Just now what we are after is thermal expansion. This is very slow, laborious, and expensive work. We ourselves have

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga., Feb., 1926. (White Wares Division.)

an expansion apparatus. We have not done much with it, but we realize its usefulness, and the thing we want to know is whether or not we can proceed along this line and do some more work.

R. A. HORNING: We made several hundred saggers by reducing the sagger mix to a dust; we watched 60 of them, and I think we have 30 left out of 17 firings. We feel we can do a great deal by carefully preparing the mix.

A. STAUDT: I consider that the shape of the article and not merely the size, is of very great significance. Has that been taken into consideration by those who have done experimental work?

R. F. GELLER: In preparing the bodies, we have calcined some of the clay, crushed it, screened it, and sized it, and used that in proportion to 50–50 with the same clay in making up the body.

Some Successful Cone 10 Sagger Bodies[1]

BY E. H. FRITZ

A MEMBER: What is the absorption in relation to the grog?

E. H. FRITZ: We assume that the absorption of the grog is the average of the absorption values of the clays used. For that reason we disregarded the grog entirely. The 3- and 12-mesh screens used in sizing the grog have openings .25 and .075 inch respectively.

A MEMBER: Assuming you had a tight grog, would that absorption be high or low?

E. H. FRITZ: It would be low. The absorption of the sagger body itself, in averaging up the values, runs very close to the same, so we have taken the average of the individual values.

E. SCHRAMM: Several years ago we made some observations on the properties of clays and clay-grog bodies.[2] We found that the porosity of a grog body was always greater than that calculated from individual porosities of the clay and grog used, and that the difference between the actual and calculated porosities increased with increasing shrinkage of the clay.

E. H. FRITZ: In this case the grog used was the same as the clays that were used; that is, just the broken up saggers.

H. P. HUMPHREY: How did you fire the saggers?

E. H. FRITZ: We fired them at the top of the kiln.

H. P. HUMPHREY: After the first firing, are the saggers sufficiently well fired to stand the weight and the high temperature?

E. H. FRITZ: Yes.

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[1] Published *Jour. Amer. Ceram. Soc.*, 9 [9], 606–12 (1926).

[2] *Jour. Amer. Ceram. Soc.*, 7, 282 (1924).

H. P. HUMPHREY: Is the temperature reached as high in the top of the kiln as it is when the sagger is fired under load the second time?

E. H. FRITZ: It is not quite as high as in the bungs between the bags. Occasionally there may be an extreme difference of three cones, but ordinarily not more than two cones.

H. P. HUMPHREY: What is the ability of a sagger to stand a heavy strain when fired at a higher temperature than it was originally fired, and possibly to go through a further reaction in the later firing? A fire brick is fired at a higher temperature than is required in service and as long as it does not reach the original temperature the action of the heat is not as severe on it as it would have been on a low fired article.

E. H. FRITZ: I believe the same is true to a large extent with saggers. If a sagger is fired higher at a later firing, it may at that time be in the lower part of a bung under heavy load, which would tend to prevent the additional shrinkage from taking place, thereby putting the sagger under great strain. We therefore attempt to keep new saggers after the first fire in separate bungs in the next fire, when they reach the regular firing temperature.

H. P. HUMPHREY: Have you ever tried firing green saggers in a kiln at a higher temperature than they are fired in service?

E. H. FRITZ: No.

W. L. SAMPLE: What was the treatment of grog?

E. H. FRITZ: It was crushed on an ordinary dry pan and screened through inclined screens, sizing it to the values given in the paper. It is then ready for the soak.

C. C. TREISCHEL: When we speak of tight-firing clays, do we mean a clay of the ball clay type, or a plastic fireclay type; that is, does a pure tight-firing clay have the same shrinkage as the clay which Dr. Schramm speaks of?

E. H. FRITZ: The Ohio No. 1 clay is a tight-firing clay, but it has the very low shrinkage of 10%. That is entirely different from a ball clay.

C. C. TREISCHEL: You still have an absorption of 3 or 4%. These clays that Dr. Schramm speaks of probably show no absorption.

E. SCHRAMM: If the absorption of the grog is known and the absorption of the clays fired at the same temperature, and the theoretical absorption is calculated the actual absorption is somewhat higher, and the difference is taken as the measure of opening of crevices or cracks in the sagger body. It is found that the average absorption is greater as the average shrinkage of the clay increases.

E. H. FRITZ: That is undoubtedly true and since increasing shrinkage shortens the life of a sagger body, it means that the ideal condition is to have a body absorption no higher than the average of the individual absorption values. In our case, we are close to that condition

since the absorption of a sagger body is within 1% of the average of the individual clays.

W. H. VAUGHN: Is a modulus of rupture of 140 or 130 lbs. worth working for at all?

E. H. FRITZ: It would be satisfactory, provided all other things are right.

W. H. VAUGHN: Have you ever made any study of absorption from repeated firings? What would the curve be like up to 15 firings?

E. H. FRITZ: We have made no study of this, but undoubtedly, the absorption decreases, especially if the saggers are fired in that part of the kiln where these were fired. They finally become very brittle.

A. S. WATTS: Have you any observation on the influence of soaking the grog or wetting it thoroughly before you put it in the clay, or was the work all done by simply spreading the clay and the grog, and then soaking them down?

E. H. FRITZ: No wetting was done until the grog and clay were spread in layers. The idea of wetting the grog previously is new to me.

A. S. WATTS: We soaked the grog before we put it in the mix, so that the wet clay would not stick to the grog as a sort of scum on the surface. This treatment gives a superior product after it is dried and fired, because there is no appreciable amount of cracking. There is an enormous weakening where the grog is dry and the clay is spread over it, and the two are wetted together. Unless the grog is very dense or saturated, it will take enough water out of the clay so that a crack will develop. We have observed that there is an appreciable weakening due to cracks along the contact line between the clay and the grog.

E. H. FRITZ: Our observations are similar, and anything which will prevent such cracking will increase the sagger life.

A. S. WATTS: Was the No. 2 Jersey clay a standard clay, or was it a No. 2 ball clay?

E. H. FRITZ: It was very much like a ball clay although somewhat sandy. Numbers 3 and 4 have 11% shrinkage but are unlike in other properties.

A. S. WATTS: Were they normal New Jersey ball clays?

E. H. FRITZ: Number 3 was a normal New Jersey ball clay, while No. 4 was more like a china clay.

A. V. BLEININGER: Frequently the average life of a sagger at the bottom of a bung is only 2 or 3 firings. We are experimenting now with a sagger mix containing Carborundum and it appears to be very promising.

E. H. FRITZ: That could be helped to some extent by using thicker sagger bottoms. We use about a 1½-inch bottom, which has helped us very much, and we get probably 10 firings from those saggers.

A. V. BLEININGER: Unfortunately, we cannot do that because the men refuse to handle saggers above a certain weight.

Sagger Clays and Properties

BY W. L. SAMPLE AND K. M. SMITH

W. L. SAMPLE: (Paper not prepared.) Our conditions were such that we had to make a sagger that would stand treatment outside of the kiln. We do not have very much trouble with the saggers in our tunnel kiln. Our plant is so constructed that we have to haul the saggers 260 feet every time we fire them. It was our problem to make a sagger that could be rolled around on the floor and banged around on iron trucks. We found that in using nothing but the large size grog screen we developed a sagger which lasts quite a long time.

Notes on Tests with Various Grog Materials

BY EDWARD SCHRAMM

A. V. BLEININGER: The question of the character of grog is important. What could be gained by the use of a particularly high grade of grog, or a special kind of grog? The tendency of using special minerals and special materials for refractories in the question of saggers is also important.

A MEMBER: In conversation recently with a man who wanted to sell some material to be used as a grog in a mix, he brought up the idea of the analogy between the manufacture of kiln products and molded products. In foundry molding practice the molder always adds a certain percentage of new sand to his mix, and then, every so often, the bulk of the sand is all thrown out and they start entirely fresh with a very small quantity of the old sand. How many of us have gone into the matter of making an addition of clay and occasionally discarding the old grog. It stands to reason that the grog gradually becomes more and more vitrified. There is more of the glass formed around the mullite, and it would probably seem reasonable to add a percentage of newly calcined material.

S. J. MCDOWELL: In one of the spark plug companies, calcined diaspor is being used as grog in saggers. The use of this material increased the life of the saggers to about double the life of the clay grog saggers formerly used. Two-thirds of the total amount of grog is new material each time and one-third is crushed saggers.

A. V. BLEININGER: We made some saggers for our plant No. 6, and introduced 30% by weight of Carborundum. These were by far the best saggers we have ever had in that kiln.

A MEMBER: Is any particular grade of Carborundum used?

A. V. BLEININGER: I could not tell you the size of mesh.

A. S. WATTS: Was it fire sand or true crystal?

A. V. BLEININGER: It is the true crystal, the real Carborundum.

A MEMBER: The cost is $190.00 for Carborundum.

C. C. TREISCHEL: Has anyone had any experience with a fired Georgia clay crushed up to form a grog?

A. V. BLEININGER: Was it a rather porous calcine?

C. C. TREISCHEL: No, this looked vitreous. It had a bright surface, as though it had been fired at a quite high temperature.

A. V. BLEININGER: Those clays are quite refractory. We have used some Georgia clay, and have had very good results but the number of saggers made was limited. There was not much of the material available.

Questions and Notes

No. 1. To what extent have fire clays been useful in sagger mixes?

A. V. BLEININGER: I understand that quite a few are using a small amount of fire clay.

D. HAGAR: We have found fire clay to be valuable.

J. D. WHITMER: We have been making a few experiments for the past year, and fired them a number of times, and have found that a fire clay from southern Ohio gives increased strength. After each firing, the curve is upward. Out of a number of clays, we have found only three that had that general characteristic. The others seemed to go up for one or two firings, then drop off for three or four, and then start up again. The Georgia kaolin was another clay of that kind.

A. V. BLEININGER: Formerly, the potters employed two or three wheelbarrows of fire clay in a sagger clay soak, but later the use of fire clay went out of fashion. In a measure the custom has returned; but it is an open question as to whether fire clay should or should not be used.

No. 2. To what extent is it desirable to use siliceous clays of the New Jersey type?

D. HAGAR: It is pretty difficult to get anyone to negative that.

C. C. ENGLE: If men, who should know, were asked what causes cracking and opening up of sagger bodies, they usually say, "You have not used enough New Jersey fire clay."

H. P. HUMPHREY: Care should be taken in using any large amount of sandy clays on account of the strength of the sagger in the raw state.

A. V. BLEININGER: There is no question but that the New Jersey clays do exercise a peculiar function. We like New Jersey clays in saggers but, unfortunately, cannot tell definitely why. We do know

that in drying, they are of considerable help and service, particularly in some plants where the drying conditions are bad.

C. C. TREISCHEL: In the manufacture of grog, a question was asked as to the function of clays in regard to the effect of dunting. Theoretically, increasing the china clay content, or clays of that type, in proportion to the ball clay content, would tend to overcome dunting. That is contrary to the experience some people have had, and the experiments they have conducted. They find that the bodies most resistant to dunting are those fairly high in silica and in ball clay content. That might apply to saggers, or it might not.

No. 3. What success has been had with the exclusive use of southern clays?

D. HAGAR: One factory has been using southern clays exclusively for four years. The ball type has been giving very good results.

No. 4. To what extent is sagger dust used in the mixes?

J. D. WHITMER: We screen out the dust, but sometimes it might be better to leave some in.

A. V. BLEININGER: We screen it out also, but sometimes we think we would like to leave some in, because we get so much of it. Should more dust be used?

J. D. WHITMER: Some of it could be used. Occasionally we run into a condition where we do not have the screen, and we put it all in. From these trials, the sagger seems to last just as well, and sometimes a little better; and I am not convinced that it is entirely good practice to screen it all out.

R. A. HORNING: We are rejecting all of the dust now, but personally, I believe it could go in. That is, we have made saggers with all that goes through the dry pan, and we have found that the whole trouble with us is that we do not keep accurate record of our results. We have made saggers with fine dust, and they have lasted some time. I believe that we would be just about as well off if we used everything that went through the grinder.

E. H. FRITZ: Our results show that it is undesirable to use anything finer than 12-mesh. Is that considered "dust?"

A. V. BLEININGER: Some people would consider that dust, and some consider it dust when passing through 16-mesh or 20-mesh.

E. SCHRAMM: It is a question of what is dust. I should put the definition of dust down to 100- or 200-mesh. It is not necessary to make dust if you do not want to. We have a hammer mill in our plant which enables us to get away from the grinding of saggers to dust.

S. J. MCDOWELL: A graduation of sizes seems desirable. The clay particles are very fine, and some grog particles very coarse.

It would seem that there should be some gradation of particle size all the way between the two. That is desirable in a concrete mix and it should also be true in ceramic materials.

A. V. BLEININGER: That is undoubtedly correct. If we could size it, we would be better off. Unfortunately, that is a difficult thing to do in an ordinary factory, at least as far as the potter is concerned.

A MEMBER: The particles in the grog seem to bunch themselves with the coarser particles in the middle, and the finer particles on the outside, which gives a strong structure, and emphasizes the value of sizing the grog.

No. 5. What should be the limiting sieves between the coarse and the fine limits, giving both the mesh and the thickness of the wires?

R. A. HORNING: Our size is 16 and 4.

A. V. BLEININGER: That all depends on the thickness of the wire. You can have a 4-mesh that is finer than a 6-mesh, if the wire is heavy enough. Our 4-mesh screen has wires 0.069 inch in diameter.

No. 6. What is the best system for drying saggers? Has the disappearance of the final "flue" drying anything to do with the lowering of the sagger quality?

C. E. JACKSON: I think that question is so tied up with the materials that compose the sagger that you cannot answer it. We have found that the best way to dry saggers is over a steam pipe. We put them on the sagger board in racks, and have steam pipes running along each tier. We have the old flue and the steam driers and there is no difference in the life of a sagger, in the manner in which we dry now.

A MEMBER: What is the flue system?

C. E. JACKSON: Suppose, for instance, this room is a sagger bank. A pipe is started down with a burner in the end, and it is followed up to the flue. It is a hot flue, running the distance that is required to dry saggers; the saggers are started down there in morning and picked up the next day. It is just a hot flue running on the floor. It is more rapid than the steam way of drying.

A. V. BLEININGER: I understand the flue system in some plants is this: First, they dry the saggers on the pallets in the regular way, with steam, but when they are apparently dry, they are taken off and put on that hot flue; this hot flue is at a considerably higher temperature than the temperature of the room, so that before the saggers go into the kiln they get the benefit of being heated on this very hot flue. Some keep them at higher temperature than others, but the fact remains that those saggers on that hot flue are thoroughly dry without question. That has seemed a most excellent practice. I still think that if we had something like this old hot flue, we would give the saggers a better chance, because the thorough heating up increases the strength

of the sagger; I have always had a respect for the old hot flue sagger drier.

R. A. HORNING: Are the saggers placed one high on there?

A. V. BLEININGER: Yes.

E. B. BAKER: In drying saggers, is it not a good policy to turn them just as soon as they can be handled? The strength of the saggers is increased if they are turned.

A. V. BLEININGER: The turning of saggers is an old practice.

C. E. JACKSON: Yes, but it is not done any more to any extent.

P. D. HELSER: We have a machine that is built of overhead carrier tracks carrying cars through the drier about 6 feet long; the heat is supplied by steam fittings, and the humidity is only that which is introduced by the drying of the saggers; the average time of drying is around 48 hours. We have no figures to compare with the former drier, but this is very satisfactory.

A MEMBER: How many saggers can you dry in that machine?

P. D. HELSER: The capacity of the drier is about 800 per day. That, of course, depends on the number of tracks. You can spread it out more.

A. V. BLEININGER: Eight hundred saggers a day is a very large capacity. It is interesting to know that that system of drying is being applied to saggers more and more.

D. HAGAR: In one factory they use exhaust gases and dry their saggers in 24 hours.

No. 7. Have steel sagger pallets been successful?

A. V. BLEININGER: We use steel pallets in one plant, and we have some cracking occasionally, but the steel pallets are excellent.

E. SCHRAMM: Are the steel pallets rigid?

F. CERMAK: Yes, an angle iron can be put on the bottom of them.

No. 8. To what extent have cellulose extracts been successful in increasing the strength of the dry saggers?

J. D. WHITMER: We have made some experiments on that, but have nothing definite to report. It seems to increase the strength decidedly.

F. CERMAK: We have been using organic binders in our plant, and we find that they increase the strength of saggers 100% without any injury to the saggers.

No. 9. Have combinations of southern wad clay with dense firing clays like the fire clays been successful?

A MEMBER: We have never been successful in using merely a wad clay and a fire clay, but have had marked success in using a small amount of fire clay: a maximum of about 15% of fire clay, 15 or 20%

of wad clay, and the remainder, up to 50%, of Kentucky or Tennessee sagger ball. We have used that in a number of cases where we found the saggers in a hopeless state, and had to do something quick in order to save a shutdown. Those general proportions have given very satisfactory results.

No. 10. What has been the life of cast saggers as compared with machine and hand-made saggers? What has been the cost of making cast saggers as compared with the regular process?

A. V. BLEININGER: We find quite a few companies are interested in the question of cast saggers, and some very fine results have been reported.

W. L. SAMPLE: We use cast saggers, and cannot say that we see very much difference in the length of the life. Our saggers are run up and down the plant. We make our regular saggers on a press. To cast saggers takes a lot of room. We can make 40 hand-made saggers in the same place that we make 20 cast saggers.

L. A. MORRIS: We had to develop a slab. We got variously from 15 to 100 trips in a tunnel kiln. In one chinaware plant the slab went 75 trips. Everybody has different conditions. The same sagger that went 75 in a tunnel kiln went 20 trips in a periodic.

W. L. SAMPLE: An advantage we find in the cast saggers is that they retain their shape better, and we use them in firing individual lids. Invariably, the bottom of the saggers will be straight and they keep their shape much better than the hand-made saggers.

A. V. BLEININGER: What has been the cost of making cast saggers, as compared with the usual process?

W. L. SAMPLE: It is very much higher per sagger.

No. 11. The treatment of raw materials.

A. V. BLEININGER: This would be a very good place to stop and bring out such factors as are of vital influence in the making of saggers. Last year, we talked of certain aspects of sagger mixes, and it might be well to add to that, if we can.

C. E. JACKSON: In preparing sagger clays the main point is to get the material as fine as possible, allow it to soak, and then double-pug it.

A. S. WATTS: What is considered to be a sufficiently fine pulverization? One shipment of clay comes in very wet, the next shipment is quite dry, and saggers are made of both kinds. If a sagger ball came in with 35% moisture in it (that can hardly be gotten into small enough lumps to handle well) should it be dried out or be put through a disintegrator?

C. E. JACKSON: The proper way would be to put it through a disintegrator. Clay with moisture should not be used if it can be avoided. Most of us can get the clay fairly dry. I have never seen good saggers made with a clay carrying high moisture. We would break it up into lumps as large as your fist.

A. S. WATTS: Do you consider that sagger clay broken up into lumps 2 or 2½ inches in diameter to be sufficiently small to put in soak?

C. E. JACKSON: Yes.

A. S. WATTS: What is the benefit and the relative cost in putting sagger clay through a disintegrator before it is distributed in a pit?

P. D. HELSER: The cost would be about $.25 a ton. Quite a few producers are now chipping their clay at $.50 a ton extra. It saves the trouble of handling, and we try to buy our clay that way. It seems that sagger clay should be in a finer state of subdivision than very large lumps.

E. H. FRITZ: We have a disintegrator at our plant, but we have not used it for sagger clays because of its location. If we were in a position to do so, we would certainly use it to break up the sagger clays, because it would be cheaper and more thorough. We have to do it by hand now. In regard to moisture, our experience has been that sagger clays do not contain more than 20% moisture, and with that amount it is comparatively easy to break them up by hand. I presume that the producers of the clay have more sagger clay available than they have of body clays, and it lies around the storage sheds longer than the body clays.

A MEMBER: There is no doubt but that a better sagger mixture is obtained if the clay is ground first. We tried that once. Or, if the clay was taken from the soak, broken up as it is supposed to be, and put it through about five times, it might be mixed up at one or two mixings.

A. S. WATTS: It would be helpful to obtain some information on the possible cost of pulverizing by a disintegrator, or some other device, as a basis on which the increased cost could be estimated before the clay goes into the soaking pit. It would also be beneficial if the clays are mixed before they go into the sagger mix. I have been repeatedly presented with specimens of saggers which showed all sorts of peculiar behavior, and asked what I thought was the matter with them. Upon examination the outline of a lump of sagger ball and a lump of something else is found and then a man wonders why, by some peculiar process of science or nature, the materials do not get together and make a strong article. The grog should also be thoroughly distributed.

E. SCHRAMM: Would there not be a danger of proceeding too far in that direction, and getting sticky clays?

A. V. BLEININGER: I think not; most of our experience is the other way.

A MEMBER: A hard clay that could not be worked up in the ordinary soaking pit was ground; the trouble we had with the clay was the dust. We are thoroughly convinced that we do not want dried and ground clays, or clays that are disintegrated.

A MEMBER: Nearly all of the plants in the East at the present time, have adopted the knife type of disintegrator for cutting up the clays. A pit holding approximately 15 tons, can be disintegrated in less than one-half a day. The uniformity of the mix has been such that all of the larger plants are adopting that mode of doing it. One plant disintegrates its clay as it comes from the cars. The side track and the machine are so arranged that as the car comes in, it is placed near a hopper in the platform, carried by belt to the pit, and by a conveyer from the pit. The clay is handled only once, two men unloading the car and disintegrating it as it comes in. In that way, they have secured uniformity.

No. 12. What has been the experience in making up the sagger bodies by means of a wet pan, rather than the soaking pit?

E. H. FRITZ: We do not use the wet pan, but I have always felt it is much more desirable than the soaking pit.

A. V. BLEININGER: I had the same thought that you had in regard to wet pans, and one was installed in one of our plants; but this wet pan has in no way, apparently, increased our sagger efficiency. In fact, that particular plant had the largest sagger consumption. Our experience with the wet pan has not been successful. We do not know why it has made such a poor showing. It ought to do it, according to all ordinary reasoning; but as far as we are concerned, it has failed. The superintendent of the plant in question asserts, however, that its use reduced the amount of kiln dirt on the ware.

A MEMBER: There are a number of us here interested in the production of clays in Georgia. We should like to get some information from the potters as to what kind of clay they want for sagger purposes. Any of us who are in the clay producing business can run that clay through a disintegrator and produce any size that is wanted. We have occasionally shipped a carload of sagger clay for which we got almost the cost of handling it, and it has not been our best clay. We really never have known what sagger clay is, but I am quite sure the clay producer could ship the clay disintegrated, if it were wanted.

A. V. BLEININGER: We are glad to have this statement.

A MEMBER: By hearsay only, I understand that someone in Illinois is grinding his grog and clay and water all together in one process. He

dumps the saggers in without breaking them up first; the grog is ground right with the clay.

A. V. BLEININGER: I should say that he would lose time in doing that.

A. S. WATTS: At Ohio State University a couple of years ago, we designed and built a small wet pan, because of the fact that we could not get a wet pan of the size that we wanted. This was more or less of a laboratory machine, about 30 inches in diameter, but in making up terra cotta bodies, we undertook to put our grog and our clay into this wet pan and prepare it very much as a wet pan material is prepared for sewer pipe. We found that we could use a larger amount of grog and get the same mechanical strength in the wet pan that we could before, when we used to make our small batches of terra cotta bodies in the soak. That is normal. It may be that in preparing the sagger body in a wet pan, a degree of plasticity is developed that would not develop in the ordinary way, or that a slightly increased amount of grog would give comparable results.

E. SCHRAMM: We have had the same experience as Prof. Watts. We installed the wet pan at our new plant, and began by putting in the same mixture in the soaking pit, but we had a lot of trouble in drying the saggers. This was especially exaggerated in our case because we were using a shale that does not develop much plasticity in the pit. However, we did exactly what Prof. Watts suggested, increasing the grog, and we still got a stronger sagger out of the wet pan than we could get out of the soaking pit.

A. S. WATTS: The mullers in the wet pan are slightly raised.

A MEMBER: Some of the unsatisfactory experiences that people have had with the wet pan method of tempering has been largely due to the fact that sagger making is mostly a piecework proposition, and not enough time is taken to develop the proper temper of the mix. Four or five years ago we found a batch going through from wheelbarrow to pile in about two minutes. Much can not be done by way of developing plasticity in a few minutes when dry grog is used.

A. V. BLEININGER: In our case, about 12 minutes is used to do that and the grog is moistened.

J. R. BOWMAN: We have always used the wet pan to make our sagger mix, but the type of the wet pan was the narrow wheel, (about a 3-inch wheel) doing the plowing, and running for 10 or 12 minutes.

E. SCHRAMM: When you run 12 minutes, does the clay get pretty hot?

A. V. BLEININGER: No.

No. 13. What should be the characteristics of clays intended especially for use on machine, as distinguished from clay for hand work?

E. SCHRAMM: I might explain what led me to ask that question. We recently installed a sagger making machine and we found that we must use the clay very hard, which was done by taking out a lot of water. Is that the right thing to do? Should we not readjust our mix, especially for the purpose of making machine-made saggers? In handling clay on the machine, we do not require the same plasticity that we do for hand work.

A. V. BLEININGER: In our own case, the situation is merely a higher grog content, of about 42% as against about 38% in the hand made. This is subject to certain variations.

A. S. WATTS: I happen to know of two cases where crude kaolin (that is, crude secondary white clay) has been used, in machine-made saggers. This does not represent more than one-fourth of the clay, but I do not know of anybody who has attempted to use a white secondary kaolin as a constituent in the hand-made sagger. The substitution of this white kaolin for a fire clay was an improvement in the opinion of the sagger makers.

A. V. BLEININGER: Of course, there are so many different types and classes of sagger clays that it is not an easy thing to answer this question.

F. K. PENCE: The workman is inclined to raise objection to too much grog in the mixture for the hand-made sagger. The tendency is to keep the grog lower in the hand-made mixture than in the machine mixture.

I also want to refer to the statement that Prof. Watts made about the kaolin going into the machine-made sagger. I imagine that the improvement happened to be a coincidence. The kaolin usually used under my observation has been bauxite kaolin, which has a tendency to offset the dunting of the sagger. The use of sagger clay of low silica content is worthy of further investigation. I also had similar experience where we used firebrick grog (good quality of fire brick) when we ran out of the sagger grog. Tendency to sagger weakness becomes cumulative; the use of the old grog in the sagger emphasizes the condition; so when dunting or other difficulty starts cropping out, it is necessary to make correction quickly.

No. 14. Transverse test of saggers and use of clays of different shrinkages.

K. M. SMITH: Figure 1 shows the appearance of the two clays after being mixed with 50% $\frac{1}{4}$-inch or $\frac{1}{12}$-inch grog by volume. The

left-hand sketch shows the clay with an individual shrinkage of 18% and modulus of rupture in transverse of 11,000 pounds per square inch at cone 10. The right-hand sketch is the clay with an individual shrinkage of 9% and modulus of rupture in transverse of 5000 pounds per square inch at cone 10. This is made from the same Ohio fire clay as mentioned by Mr. Whitmer under the question "To what extent have fire clays been useful in sagger mixes?"

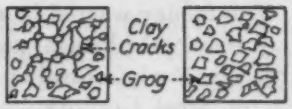

FIG. 1.—Right: Clay cracks that expand as they approach a piece of grog, due to high shrinkage of the clay. Left: Notice that no clay cracks developed, due to lower shrinkage of the clay.

E. H. FRITZ: The subject is closely tied up with what I discussed above. Very likely that condition is due to the shrinkage of the clay which was used with the grog; in the first case the shrinkage was probably very mild, and in the second case there was a low shrinkage of the clay.

No. 15. Sagger failures and their remedies.

F. K. PENCE: Some days ago we had a discussion among the tile manufacturers. The engineers and the manufacturing men were talking about their troubles, and we were talking about sagger problems. One man said he had been in a terra cotta meeting. He had heard them talking about the care they had to use in making those pieces of terra cotta; the close attention they gave to dry the saggers carefully to avoid checking; and yet when we make saggers, we rush the preparation of the clay; the fact of the matter is, we could not make a sagger that would be fit for terra cotta work. Saggers are made without attention to all details. We rush them through and ignore the checks and strains and crumbly edges, and then we talk about high sagger loss. If we made a sagger with the same degree of care that we do the product that goes out to the trade, we would get along better.

FACTORY MANAGEMENT—THE PIVOT MAN AND HIS RELATION TO INDUSTRY[1]

BY W. E. DUNWODY

Industries are paying each year a bill of added operating expense which is many-fold what it should be because of wastes. It is important to know what these wastes are and how they can be greatly reduced in industry through proper leadership and management.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Feb., 1926, Atlanta, Ga. (Heavy Clay Products Division.) Received January 15, 1926.

The money wasted in a single year in six American industries would buy the total physical assets of the Pennsylvania Railroad Company, the New York Central lines, the Ford Motor Company, and the United States Steel Corporation, and leave more than a billion dollars in small change.

Can you comprehend an amount of that size? Just think of it! Five billion, five hundred and twenty million dollars of waste in one year! That is more than 18 million dollars a day. And that is not half of it!

Three or four years ago a group of the country's most eminent engineers undertook to find out how much was being wasted by American business. They chose ten industries and said: "Now we shall make a complete survey of these ten, and on that basis we shall compute how much money is being thrown away because the hand and brains of business—the employers and employees—have not found out yet how to work together."

They surveyed six industries as completely as they could. One of the other four declined to be surveyed and the records kept by two others were so woefully incomplete that, after five months of work, the engineers gave up. The tenth industry was not surveyed, so far as anybody can discover, probably because by that time the engineers were weary.

In the six industries surveyed, the engineers were unable to do more than scratch the surface because (1) there were scarcely any standards of comparison, (2) no records from which accurate deductions could be made, and (3) few, if any, had any facilities for measuring the cost of labor turnover, overhead, and other vital "intangible" costs. But the investigators were at last able to show a total of five and one-half billions of dollars wasted in one year alone in only six industries.

Charles M. Schwab estimates the total loss for all industries at thirteen billions, six hundred millions. Harry Emerson, the noted industrial engineer, says 50 billions.

If the investigators had added to the five and one-half billions for six industries the very conservative estimate that labor is only about 65% effective, the total waste would have mounted to nearly seven billions.

When Herbert Hoover was asked to have the Department of Commerce adduce some data that would make the figures complete he threw up his hands. The records did not exist.

But there are five and one-half billions of dollars thrown away in small wastes, small mistakes, lack of interest in the job, indifference, failure to team up, failure to apply common sense to business relationships, failure to coöperate.

At the same time that the five-billion-dollar report was published, large losses were caused by strikes and lockouts, the most appalling in the history of the country. This too, in view of the fact that industry was then spending more money than ever before on such incentives as bonuses, profit sharing, "industrial democracies," "welfare work" various forms of worker participation in management.

The trouble which was taking the very lifeblood out of industry and which is still affecting industry, was that with all the spending, the industry had not found a way to prove to workers, department heads, superintendents, foremen, etc., that their interests were identical with those of the firm, that as one prospered the other prospered, when one failed, the other failed, and that there was one rule only for mutual profit and prosperity and that was teamwork.

In the early days of American industry few shops had more than a half-dozen workers, and every worker was a craftsman. But as the time went on and the demand for goods increased, the craftshops were forced out of existence. They were replaced by larger organizations, in which each man made one part or did one operation. But as organizations became more efficient, they unfortunately became more hard-hearted. The "boss" hired and fired promiscously. When a man did not fit, out he went. Neither his troubles, nor his aims, nor his mental processes were of any concern to the man higher up.

It may be said to the credit of the owner that the rapidly growing business was not so much to blame for his failure to get along on a really profitable basis with his workers. There was no time to give to the matter. He was fully occupied with the sales and financial ends of the enterprise. When the workman-owner retired to a private office, he made his best workman a foreman; and, as business grew, he appointed from the better of his employees, a general foreman, shop superintendents, general superintendents, and so on.

These men were selected because of their proficiency as workmen, and without much, if any, regard for their natural capabilities for managing men. Their only weapon was fear. When criticized for high cost of production, their only recourse was to speed up on their footwork, yell louder at their men, or fire a man here and there, as an "example" to the others. It was a grim game. The boss said, "I am paying you so much for ten hours of your time. I am going to get all the work I can out of you in that time. If you loaf without my catching you, you win. If I catch you loafing, you lose your job."

After a little while the workmen hated the foreman, and even hated the employer whom the foreman represented. The worker became fertile soil for the seed of discontent. He gave as little as he could for as much as he could get. It is small wonder that there sprang up in

industrial organizations a whole army of frictions, which resulted in such costly things as high labor turnover, excessive overhead, waste, mistakes, carelessness, indifference, indeed, open hostility, and a thousand other costly ills which continually threw the whole organization out of gear and resulted in discord, trouble, and loss!

The foreman did not have the conception of himself as a "pivot man," a manager and leader of men, a pivotal point on which and around which the human organization revolved. He had authority and proceeded to exercise it. He had not been given the larger vision of himself as a leader.

The crying need of business today, and the need which tens of thousands of concerns throughout the country are meeting, is the development of real pivot men; men and women who are not merely "bosses" but who think themselves to be and who act as teachers and leaders of the individual members of their groups. Such pivot men know that their most profitable possession is not authority, but the ability to shape and guide the thought and action of their workers, and inspire them to give the best of their efforts, both of brain and hand to the job.

Two things are necessary for this. The first is, the confidence and respect of the workers for the pivot man. Complete mastery of the technical aspects of the job, the ability to do it as well, or better, than the best workman in the group, wins this respect and confidence. It establishes the pivot man in the worker's mind as one to whom he can look up.

The second indispensable qualification is ability to "sell" sound constructive thinking to his workers, to replace wrong thinking, petty prejudices, and incorrect viewpoints.

He must constantly make it his business not only to see that each individual job is turned out according to standards, and that quantity is maintained, but also that his workers' thinking is kept in harmony with the principles of sound economics, that they are not led astray by shallow thinkers, or by their own lack of education, that they are thinking along with their firm and bending their efforts toward the firm's success and progress in order to assure their own welfare.

The men must pull together with the pivot man for mutual progress, reasonable costs, absence of waste and mistakes, permanency of employment, low overhead, greater profits for the firm, and a spirit of coöperation and friendliness which makes for the most pleasant kind of working conditions.

Pivot men may be developed by entrusting their training in human leadership to an organization of specialists in that science, an organization which has background, the experience and the facilities to carry

the work through to a successful conclusion. None but the best organization in this field is big enough for the job—for it requires deep understanding of human nature, wide experience in dealing with all types of men and women, ample means of supplying a service covering every angle in a practical manner, and a large enough clientele to enable it to supply the service at a reasonable cost.

The enterprise of which I am an executive has had a most agreeable and profitable experience along this line during the last several months. We turned our problem of pivot man development over to a Chicago organization. By means of a series of weekly letters and monthly publications, combined with regular meetings of our pivot men at which the various problems of man management were discussed, we have accomplished dollars-and-cents results which have amazed us. And the work still goes on. We feel that we have already been well repaid for our small investment.

460 Broadway
Macon, Ga.

THE HUMAN ELEMENT IN BRICK MAKING[1]

By James P. Martin

Successful brick making depends on three elements: physical, mechanical, and human. If we had stated these elements in order of importance, the human element should come first.

It is important to have suitable clay or shale and suitable machinery, but it is most important to have the human element qualified to control the physical and the mechanical elements.

We study and write on clay mining, clay delivery, clay preparing, brick making, drier, and kiln equipment. The real purpose of this paper is to invite a study and discussion of the human elements in brick making, and, perhaps, open new lines of thought in solving some of the problems in brick making.

Example of Importance of Human Element

In a certain location we built complete plants for neighboring brick manufacturers. Each had been manufacturing brick for years and each had been fairly successful. Their clay deposits were practically identical in quality; they had equally large daily capacities and they served the same market. Plant "A" was first equipped with modern mechanical elements from clay bank to kiln and a year later plant "B" was similarly

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equipped. Plant "A" has now been operating for five years and has earned a satisfactory profit each year; one year as much as $300,000. Plant "B" has now been operating for four years without profit any one year. Since the physical elements and the mechanical elements are practically identical, it seems fair to assume that the human elements have been responsible for as much as approximately $300,000 yearly difference in profit.

The organization, the human element, on plant "A" adapted itself to new conditions, but the organization on plant "B" did not adapt itself. Is is not just as much worth while to try to solve this problem as it is to study savings in drying or firing through adjustment or revision of the physical and mechanical elements?

Operators Must Think

On one occasion we were answering a customer's complaint that the machinery was not operating successfully. When our field engineer got on the job the machine operator placed the responsibility with the mechanical elements. The first advice given him by our field engineer was that "the man who operates a piece of machinery should at least have as much brains as the machinery has." The suggestion was effective. The operator had brains; he simply was not using them. But he is now, and complaints no longer exist.

Perhaps we shall find a solution for our problem in encouraging the human element to use its brains, to think.

This suggestion applies not only to the men in the clay bank who mine the clay with pick and shovel but all along the line up to and including the manager of the plant.

It has been aptly said that "the most difficult thing in business is first getting yourself to think and then getting others to think." It is very easy to keep so busy that no time is left over for hard, quiet thought, for thinking through from the beginning to the end.

Brick making includes many jobs that are monotonous. When one thinks of the man who does identically the same thing year in and year out, one does not wonder that there is encouragement for carelessness and neglect and a lack of incentive to think. The monotonous job palls on any of us. If we can find some way of making the man doing the monotonous job interested in that job then we are going a long way toward finding the solution for our problem.

Men in Clay Bank Should Study Clays

The man in the clay bank may have a monotonous but important job. Upon him may depend success or failure of the entire brick plant. A large number of brick plants depend for success upon a proper mix-

ture of the clays. The wages of the men in the clay bank represent a very small proportion of the cost of manufacture. The waste may exceed the wage expense many times over. It would seem to be of economic advantage to make interesting the job of the men digging the clay; make it worth their while to think.

Machine Operators Should Think How to Increase Production

The men operating the machinery, too, have monotonous jobs. And how often we see machinery abused and neglected. Dust and dirt is allowed to accumulate over the machinery and get into the bearings. Oil and grease are either wasted or not properly used. Production is affected and heavy repair bills are a consequence. Men should be trained and encouraged to keep the machinery properly lubricated and clean.

The brick manufacturer who has the least repair bill is the one who keeps his machinery clean. One plant required the men to rub down the machinery free from dirt or grit at the end of each day's run, just as the modern machine shop expects men to keep their machine tools clean.

The loss of production or excessive repair bills may be a greater percentage of the cost of manufacturing brick than the actual wages paid, and a reward for faithful attention to duties may prove an economic gain.

At one plant, when the whistle blew for dinner, every man would rush away thinking only of the hour's freedom, and nothing about the condition of the machinery for the afternoon's production. The superintendent of this plant put into effect a plan whereby the men were rewarded for continuous hourly production. The plan included noon inspection of the machinery. During the noon hour each man tightened up bolts, added lubricant where necessary and made ready his machine for the afternoon's work. When the day's work was finished another inspection of the machinery was made and any part that showed excessive wear was either adjusted or replaced. The machine was cleaned down and everything was ready for the next day's work. We know that the actual saving on the repair bill at this one plant was as much as 50% compared to its expense bill prior to the time this plan went into effect. To this must be added the dependable daily production that has so important an effect on the net profits.

Savings in Boiler Room

It is a rather monotonous job to fire the boilers every day. The human element can easily fall into the habits of carelessness and neglect, and pay no attention to the amount of fuel consumed. The

firemen probably thinks it does not make any difference to him whether he fires more or less coal. He has the job to do and he gets paid just so much for it so why do any serious thinking about it. But here is another opportunity to make the monotonous job interesting and encourage the operator to think.

On one plant the night fireman was using five tons of coal to dry the brick. He was told that while this seemed to be the average fuel consumption over a long period of time, nevertheless, there were possibilities that it could be reduced and the company would make it worth his while to think out some plan for economizing the fuel. A reward of $2.00 per ton was offered as a bonus to his salary for every ton of coal saved under the average amount, with the result that he became interested in his job and has actually saved this company an average of one ton of coal per day ever since, and dries the brick just as satisfactorily and in the same time as before. This ton of coal was worth to the company $5.00. The fireman received a $2.00 bonus but the company received a $3.00 bonus. Prior to that time the entire $5.00 per ton cost of the coal was included in the cost of manufacture. Over a period of a year the fireman earned an interesting bonus; so did the company.

Bonus Makes Kiln Firing Interesting

We have just one more illustration. It affects the firing. There was a plant obtaining approximately 80% No. 1 hard brick per kiln, and consuming an average of forty tons of coal. It became quite a problem to dispose of the accumulated salmon brick at $5.00 per thousand less than the hard brick. The manager worked hard with his firemen but got nowhere toward the solution of the problem until finally he decided to make the job interesting by rewarding the man who would think. He offered $25.00 bonus per kiln for every kiln produced with over 90% hard brick and $2.00 per ton additional bonus for every ton of coal saved under a certain amount. Today on that plant not a single kiln at any time produces less than 90% hard brick and most of them produce over 95% hard brick. There has also been a considerable saving in fuel.

Plant Executives Must Study and Exchange Ideas

The brick business is improving. The improvement has been decidedly rapid since 1920. More antiquated mechanical equipment and more inefficiency has been eliminated since that time than for triple the period of time before. One of the best evidences that the brick plant is improving is the interest taken by the executives in trade associations and in the AMERICAN CERAMIC SOCIETY. Executives are

now being forced to a more exact knowledge of the details of their business. They are coming to appreciate the opportunities offered through exchange of ideas in meetings like this one. Every man in the business should feel encouraged with the prospects for the future of the ceramic industry. It is steadily climbing on to a higher plane and to the prestige that its honorable tradition entitles it to.

Ford, Firestone, Edison, and Burroughs each year took an outing together. Each had their respective camp duties. On one occasion they pitched camp in Virginia and it was Henry Ford's duty to gather the wood for the fire. At a dilapidated farmhouse there was a pile of logs in the yard. He was granted permission to take what he needed of these logs but it was necessary for him to saw them. One of the family, a lad of about twelve years, offered to help him saw the logs. Henry Ford was on one end of the buck-saw and the lad on the other end. Mr. Ford said to the boy "Do you know with whom you are sawing wood?" The boy replied "No Sir" and Mr. Ford then said "I am Henry Ford." The little fellow looked up and said "Do you know who I am?" and when Mr. Ford said that he did not know, the boy replied "I am Robert E. Lee."

It is well to get acquainted with the fellow on the other end of the buck-saw. He may not know as much as you do but he knows something and an exchange of ideas help both. The AMERICAN CERAMIC SOCIETY is sawing wood. We hope and we believe that organizations like this one will more and more attract the executives of the brick plants for a discussion and study of the problems of their business, not only as it affects the physical and the mechanical elements, but also as it affects the human elements.

LANCASTER IRON WORKS
LANCASTER, PA.

RUBBER, AN EFFECTIVE MATERIAL TO RESIST CORROSION AND ABRASION[1]

BY B. W. ROGERS AND H. E. FRITZ

The peculiar properties of rubber and the wide variation of its possible and effective uses, has made it a very popular material in the solution of many long-standing problems. Such properties as elasticity, resiliency, flexibility, dielectric quality, and moisture resistance are well-known, and have been made use of for a long time. The effectiveness of rubber as an abrasion and corrosion-resisting material has come into prominence within comparatively recent years, and a survey of many varied industries has given mechanical rubber goods manu-

[1] Presented at the meeting of the Associated Technical Societies of Cleveland, May, 1926.

facturers an opportunity to study and develop new forms of rubber for applications that are unique as well as economic.

A great deal of effort has been exerted in the rubber compounding art, which has resulted in thousands of formulas, each having its own peculiar property for a specified service. The range of physical properties, uses, and cost of the many different rubber compounds is probably as great as the variation in iron and steel and their alloys. For this reason it is always advisable to consider carefully the service, and select a suitable compound.

Corrosion

There has been a long-felt need particularly in the chemical and allied industries for a corrosion-resisting construction material such that when subjected to general factory conditions, it would be serviceable over an appreciable period, regardless of shock, strain, and vibration, which are often present to a degree sufficient to eliminate the use of any fragile material. Such a material would greatly decrease replacement and maintenance cost, and might lead to a revival of chemical manufacturing processes which are in the discard as a result of the absence of a suitable construction material.

Rubber has been found effective in meeting the need of many corrosion-resisting applications, and is finding a wide use. The field has appeared sufficiently attractive for large rubber manufacturers to concentrate their efforts on producing compounds to resist corrosion effectively, and rapid progress has been made in the solution of manufacturing problems and methods of mechanical attachment. Rubber is now effectively resisting, without contamination, all the acids except nitric, acetic, highly concentrated sulphuric and phosphoric. Rubber will successfully resist the corrosion of 50% sulphuric and 75% phosphoric, and the common corrosives such as muriatic and sulphurous acid, and salt solutions present no problem at all when stored and transported in rubber-lined containers.

Abrasion

It has been known for some time that a good grade of rubber has a remarkable ability to resist abrasion and special study has been given to the compounding of rubber for various abrasion-resisting service.

An example of the abrasion-resisting quality of rubber is the protecting cover of conveyer belts which carry millions of tons of sharp abrasive ore and rock materials before the failure of a cover thickness often not exceeding one-eighth inch.

The shell of a 5 x 22 ft. grinding mill in a cement plant charged with 45,000 pounds of steel balls was lined with rubber one inch thick made in flat sheets. During the manufacturing process, a piece of gauze was

placed between the rubber and the curing press, leaving a permanent cloth imprint on the surface which was exposed to wear. After ninety days of continuous operation the wear on the rubber had been so slight that this cloth imprint was not yet removed. After fourteen months of continuous service the wear did not exceed $\frac{1}{64}$ inch from the original thickness.

A large manufacturer of Carborundum requires the use of a machine to mix finely divided abrasive material, and bronze arms were used in the mixer to eliminate undesirable contamination. These bronze-wearing parts gave a life of only six weeks, and were a source of trouble and expense. To test its effectiveness one of the arms was covered with one-eighth inch rubber. This thin coating has now been in service for ten months, and is reported to be still in excellent condition.

The operators of a sand dredge in the Ohio River placed a sheet of rubber at the discharge of a 36-inch conveyer, and there was concentrated over a very small area in a period of 7 months the impact and scouring action of 250,000 cu. yds. of sand and gravel. It was observed that the rubber outlasted ten steel plates of the same thickness, and in the same service with a substantial saving in cost over a steel lining and an incidental saving of time and labor. It was remarked that had this plate of rubber been shifted and favored, so that the wear would have been more evenly distributed over the entire surface, it could have been made to deliver forty times the service of the same thickness of steel.

A number of other similar instances could be cited where rubber when properly applied is meeting the need as an effective covering in places where abrasion is present to a destructive degree. These few are sufficient to indicate that the field of useful applications will have a very wide range.

The Vulcalock Process

It has long been the aim of chemists and rubber process engineers to discover a method of attaching soft rubber to metal, more securely than the adhesion afforded by cement or glue. A mechanical anchorage can be effected between a metal surface and hard rubber and in turn an adhesion between the hard and soft rubber, but this method is not considered altogether satisfactory from the standpoint of cost, and the lack of flexibility. A large Akron rubber manufacturer has discovered a process which permits of soft rubber being applied directly on a smooth metal surface. Adhesion between the two materials is so complete that they appear to be integral, and the bond approaches the tensile strength of the rubber itself. Adhesion tests have been made to show a strength in excess of 700 pounds tensile to the square inch. The end of a steel bar with one inch cross-section area was attached by

the Vulcalock process to another piece of steel, and the strength of this bond was demonstrated by supporting weight of two large men without any sign of failure. This new process has been found successful also in attaching rubber to other metals, such as brass and aluminum, also to wood and concrete.

The Vulcalock process brings into use a new industrial material which incorporates the strength and workability of steel with the desirable abrasion and corrosion-resisting surface of rubber. The attachment requires processing the metal surface and special preparation of the rubber stock in its uncured form. The pliable, semi-plastic gum is applied to the metal and cured in place, and it is during the curing operation that the remarkable adhesion is set up.

The only limiting factor of the Vulcalock attachment is heat, and at present its application cannot be conservatively recommended where the temperature exceeds 180°F.

Rubber Ball Mill Lining

Some of the metalliferous ores that have to be finely ground to free the mineral content, are very abrasive in nature, making the steel consumption in the grinding operation excessive and costly. It was at the Nippissing Mines at Cobalt, Ontario, Canada, where a hard quartz silver ore is being ground that a mining engineer conceived the idea to use rubber as a mill lining. The first experiments were made early in 1921 and it soon became apparent that the rubber lining showed excellent wearing qualities and the observations were turned to other factors of performance, such as the effect on power consumption and grinding efficiency.

A close check demonstrated that there was a capacity increase of 15% without increased power consumption, and without sacrificing the desired fineness of the discharge. Also a reduced slippage of the grinding media against the shell lining was noticeable, and the consumption of grinding media was 8.8% less per ton of material ground after the rubber lining was installed.

After the first few installations had been made, and the basic principles found to be sound, the development of a commercial lining was given thought along two separate lines: first, to produce a standardized lining that could be installed in the field without making any objectionable or costly changes in the construction of the mill, at the same time giving the rubber a positive anchorage in the mill, and eliminating metal from wearing contact; second, to determine the limitations of the lining in regard to varying conditions of operation, so that recommendations could be made to prospective users with some assurance that a saving would result.

It was found that in most dry grinding operations heat is generated by friction, which sometimes builds up a temperature sufficiently high to cause a premature failure of a rubber lining. Rubber linings should not be considered for dry grinding applications where the temperature exceeds a conservative limit of 180°F. Laboratory and field tests show that severe impact will destroy the structure of rubber and resistance to impact varies in direct proportion to the thickness of the rubber. Therefore, as the size of individual balls, which make up a grinding charge, increases, a rubber lining must increase in thickness in proportion sufficient to absorb the impact without a damaging effect. From the many tests it has been concluded that the rubber lining is best suited for cylindrical type mills used in the wet process grinding of fine materials, requiring small balls, that give a large grinding surface.

The rubber lining is being adopted in the Portland cement industry for secondary wet process grinding to take advantage of the longer life of the rubber, and where comparative tests have been made, rubber-lined mills are showing increased efficiency ranging up to 20%. Efficiency should take into consideration the combined factors of capacity, fineness, and power consumption, and in the case of the rubber-lined grinding mill, the reduced power consumption is the primary contributing factor in the efficiency equation. Power is saved by reducing the slippage of the grinding media on the shell, and the substantial difference in weight between the rubber lining and steel lining is a contributing factor in favor of the rubber lining.

The rubber lining probably finds an ideal application in ceramic grinding operations because the contamination of white pigments is negligible, and the impervious smooth surface of rubber permits the mill to be washed out clean when color changes are necessary. The construction of some small batch mills used in the ceramic industry permits of the lining being cured into the mill by the Vulcalock process, eliminating all joints and crevices, which are objectionable from the standpoint of the ceramists.

Some chemical manufacturing operations require pigments to be ground in contact with corrosive liquors. This presents a problem of protecting the interior of the grinding mill from corrosion as well as abrasion. Rubber offers a solution to this combination, and the Vulcalock process makes it possible to line a mill completely without seams, so that corrosion protection is complete and positive.

The field opening up for new uses of rubber, involving its abrasive and corrosive-resisting qualities, is broad, and the surface has hardly been scratched. The percentage of economic applications that can be conceived by the rubber manufacturers is comparatively small, which makes it necessary to reach out and solicit suggestions and coöperation

from the entire fraternity of engineers who are looking for new methods and materials that can be applied economically to their particular activity.

GOODRICH RUBBER COMPANY
AKRON, OHIO

THE MANUFACTURE OF SPIRAL ACID RINGS[1]

BY B. MIFFLIN HOOD

Previous to the World War we were furnishing most of the chemical and fertilizer plants of the South with their acid resisting tower packing. In a brief time we saw sulphuric acid rise on the market 400%. It was in very great demand because of its use in high explosive manufacture.

Years before the war, I. Hechenbleikner came to North Carolina from Austria and under contract with J. B. Duke and the Southern Power Company built the first atmospheric nitrogen plant in the United States and the first phosphoric acid plant in the South. He used stoneware and brick. It was the first time that towers were built of brick with acid proof cement and in place of lead to house the tower and to act as a container for the chemical reactions.

FIG. 1. Cross-section showing construction.

Hechenbleikner had the idea that a cylinder of clay made in one process with a spiral or helical plane would produce a more scientific and efficient chemical tower packing.

In 1916 in coöperation with Charles L. Krager and J. W. Thomas experiments were carried on at the quarry floor tile plant at Melville, Tenn. It was soon apparent that a double shaft auger machine would be the best machine. Maximillian Mueller was called into conference resulting in Thomas attaching his spiral ring die to the Mueller improved double shaft auger machine and producing on one machine one hundred thousand 3-inch rings per day.

The improvement made in the auger machine was a solid shaft which formed the spiral revolving at a much higher rate of speed while the auger blades on the hollow shaft formed the cylinder. The clay issued through the die, propelled by both forces in unison. It was perfectly bonded as it issued from the die.

FIG. 2.

With this packing the mixing of the gases and liquids were intensified like the whirl of a pool or twist of a tornado, making it necessary to build towers only one-half as large to get the same efficiency.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga, Feb., 1926. (Heavy Clay Products Division.) Received April 3, 1926.

The rings were automatically cut and transferred from off-bearing belts or brick drier cars. In the drier it was found necessary to give more attention to humidity conditions than had been necessary in brick drying to prevent cracking.

In the kiln the rings were staggered and stacked nearly to the crown and vitrified to a dense glassy body.

Previous to America's entrance to the war these rings were shipped to high explosive companies in Canada, Norway, and in the states to duPont, Atlas, and Aetna, and numerous chemical manufacturing plants. When America entered the war the spiral rings were used in the manufacture of poison gases.

About eight million were used at Plant One, Sheffield, Ala., 55 million at Plant Two, Muscle Shoals, and orders came in from all the power plants built by the War Department, and all picric acid and ammonium nitrate plants.

Twenty-three plants were in operation producing spiral rings and chemical stoneware for our Company. In 1918 we had, at one time, unfilled orders of 7,000 carloads.

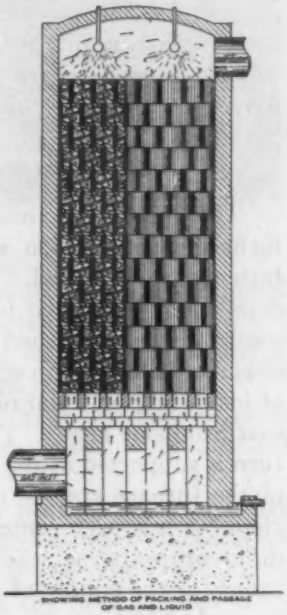

FIG. 3.

Over twenty million rings were salvaged from the war and marketed in the oil, gas, and chemical industries. During the past year over one million were shipped to Argentine Republic and Honolulu.

B. MIFFLIN HOOD BRICK COMPANY
ATLANTA GA.

A MODERN FRIT FURNACE[1]

BY W. C. STIEF AND S. E. HEMSTEGER

Introduction

During the past years the process used in the making of frit has been very crude and has always been looked upon with considerable hatred and contention. It has been relied upon for centuries, handed down

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga., Feb., 1926. (White Wares Division.)

from generations, probably because of tradition, as the only safe method to follow in making a frit. Notwithstanding the fact that in ceramic plants practically all other details of production have advanced and improved, frit continued to be melted in saggers or brick-constructed smelters, and not until late years, since the advent of the rotary smelting furnace, has any material improvement been made for the production of frit in a more efficient and economical manner, paralleling our other modern methods of production.

A Description of Rotary Smelting Furnace

The melting chamber or cylindrical part of the rotary smelting furnace consists of a sheet steel drum with a cast iron cone head fastened at each end. The one cone head is equipped with a hinged door which is opened for charging purposes, while the discharging of the frit is accomplished from the other end. This cylinder or melting chamber is lined with special shaped fire brick, back of which is a layer of insulating material placed against the sheet steel drum and the two cast iron cone heads. This melting chamber rests in a cradle, which in turn is supported at the center by two trunnions resting in the bearings of the furnace stands, one on each side of the furnace. The melting chamber is so well centered that it is quite easy to tilt the furnace into different positions when so desiring. The oil burner, which is the agent for the supply of heat to furnace, is so constructed as to be able to produce various types of fires such as oxidizing, reducing, or neutral. The burner is installed at the charging end of furnace and can be raised or lowered out of position for charging purposes.

Power and Equipment

There are two motors required in operating the furnace: a 2 h.p. motor to revolve the melting chamber and a 7½-h.p. motor to run the blower supplying a 2½-pound air pressure to the oil burner. 22–24 Baumé oil is supplied to the furnace at 35 pounds pressure. It required about 230 gallons of oil to produce 7250 pounds of calcine frit. A 1½-inch steam ejector raises the hot water from the quenching frit each time after discharging the furnace.

Operation and Method of Smelting

The 1200-pound raw batch is quickly charged into the preheated furnace through the charging door by hand shoveling (Fig. 1). The melting chamber of the furnace is then partially rotated to put the charge on an angle of approximately 35°, or its reposed position.

After the raw batch has been exposed for a very short time to rays of heat which are reflected from the hot brick lining of the furnace, the surface becomes caked or hardened, thus preventing the raw material from being blown through the discharge end of the furnace when the burner is lighted. As soon as the burner is relighted the frit commences to fuse and flow down the inclined surface to the bottom of the furnace, forming a bath and leaving a fresh surface of the raw batch constantly exposed to the heat. This process embodies two important features:

FIG. 1.

1. The melted frit is free from any danger of overfiring, for it is being constantly kept at the fusing point of the charge.

2. The unmelted material is exposed to the heat and rolls or curls into the bath, reducing the melting time and consequently the fuel consumption.

The partial rotation is continued, one layer melting after the other until the entire charge is fused. After this is accomplished the rotation of the furnace is continuous (Fig. 2), causing the white hot lining from above to be brought below, as well as the heat applied from above. This continuous rotation quickly increases the temperature of the melted or fused bath and the entire charge is matured within a very short time.

FIG. 2.

After the frit is fused, the furnace is tilted for pouring by turning a large hand wheel, and the flow of the fused material is under the complete control of the operator (Fig. 3). Care should be taken in designing a means for quenching the frit so that a sufficient depth of water can be maintained in order to pour the melted frit quickly. It is possible for us to melt a 1200-pound raw batch, quench the calcine frit, and recharge the furnace in a total of 2 hours and 40 minutes, thus giving 7015 pounds of calcine frit per 24-hour day.

After a period of investigation to determine a suitable raw material mixture which fuses readily, we were successful in producing a very uniform composition calcine frit; also one which pulverizes easily.

The condition of the lining is surprisingly well preserved after 21 days of intermittent operation of the furnace, and indications point out that it will survive many more days of duty.

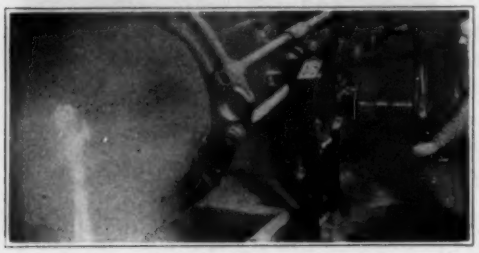

FIG. 3.

There is always a certain amount of smoke accompanied by the lighting of a cold furnace and the relighting after a fresh charge has been put into the furnace. During the melting of a charge the combustion gases of the oil burner are also forced through the discharge end of the furnace into the furnace room. Consequently the adoption of artificial devices was resorted to in order to clear the atmosphere of the furnace room. Two large overhanging hoods, one at discharge and one at charging end of furnace together with two suction fans take care of these gases.

The Comparison of Costs

From the investment standpoint the adoption of the rotary furnace in preference to making frit in saggers is quite profitable. Astonishingly high costs result in resorting to the saggers as the container for calcining frit. Actual calculations show that the frit which we use in one raw glaze charge costs $3.77 if made in saggers. This same amount of frit costs $1.38 if made in the furnace. The saving of $2.39 on every mill of glaze will completely pay for the initial cost of the furnace and equipment in three years. There is also a recognized saving by an increased production in both bisque and glost kilns by firing ware in place of saggers and frit.

At the plant where the operation described is in use the rotary furnace is in operation only two weeks per year. However, the investment is capable of much greater production as growth of business requires. Consequently, a greater production will pay for the investment even sooner than stated above.

Conclusions

Frit made in the rotary smelting furnace contains superior qualities over frit made in saggers. These outstanding qualities are (1) uniformity of composition and (2) the frit being capable of grinding easy.

The furnace investment paid for itself in three years out of fuel, saggers, and labor savings.

MT. CLEMENS POTTERY COMPANY
MT. CLEMENS, MICH.

NOTES ON FELDSPAR TESTS[1]

By W. L. Sample

ABSTRACT

A method of making fusion tests, particularly the shape of the test piece, and the bond used.

The correct method for testing feldspar is to use the feldspar in a batch. Some mix the feldspar with water, and make a short dumpy cone. This is good, for some idea can be gained of the comparative fusion. A tall, slender cone has a tendency to squat all at once. Using a solution of gum tragacanth[2] to form the bond, and making the piece in the shape of a tapered cylinder has been found to have many advantages. The mold should be made open at both ends, being merely a slightly tapered hole through a plaster slab. The illustration shows an unfired cone (top-right) which will give an idea of the shape of the mold.

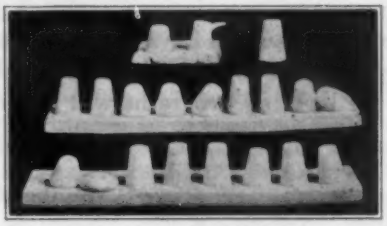

Fig. 1.

Figure 1 shows (top-left) feldspar from successive cars from the same firm. This shows a lack of uniformity, the last car appearing much softer. A trial of this feldspar in a batch showed this to be true. The middle and lower exhibits show tests made of seventeen different feldspars from different firms. It is comparatively easy to differentiate between the soft feldspars but for the harder feldspars it is necessary to examine the edge at the top of the cone, the edge being more rounded on the softer feldspars. The illustration does not show this so well.

The cone, being hard, can be sandpapered to a sharp edge at the top, this edge showing the fusion before the piece squats. The shape appears to be the happy medium between the short cone, whose squatting is hard to observe, and the tall cone, which squats so rapidly.

Cambridge Sanitary Manufacturing Company
Cambridge, Ohio

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[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (White Wares Division.) Received June 5, 1926.

[2] Gum tragacanth can be obtained at any drug store. A quarter of an ounce of gum placed in a quart of water, and allowed to stand for two days will make solution enough for many cones.

ACTIVITIES OF THE SOCIETY

TWENTY-NINTH ANNUAL MEETING

The Detroit local committee is all set to receive and to entertain during the week of February 14, 1927.

Book-Cadillac Hotel will be headquarters. We advise making room reservations early.

Invitations are being received from Michigan ceramic manufacturing firms to visit their plants.

One and one-half fare excursion plan has been granted by all the passenger associations.

The several Divisions are working hard at their programs; some papers are in and abstracts of others are furnished. Evidences are that the meeting programs will be unusually valuable.

Membership Solicitation

Monthly Record of Acquisitions

	1925		1926	
	Personal	Corporation	Personal	Corporation
Dec. 15–Jan. 14	24	1	37	7
Jan. 15–Feb. 14	21	4	62	8
Feb. 15–Mar. 14	14	3	15	3
Mar. 15–Apr. 14	9	1	11	3
Apr. 15–May 14	15	3	11	3
May 15–June 14	15	2	13	
June 15–July 14	16	1	5	
July 15–Aug. 14	12	1	5	
Aug. 15–Sept. 14	9	2	15	2
Sept. 15–Oct. 14	14	1	18	1
Oct. 15–Nov. 14	26	3	19	5
Total	175	22	211	32

Although the record above shown is an improvement over that for 1925, it would seem certain that since persons and corporations are not only willing but anxious to join when personally solicited, these numbers could be greatly augmented. The SOCIETY now enjoys the support and subscriptions fully paid up of 2481.

The real service rendered by the members in collaboration through this SOCIETY is of value to ceramic manufacturing concerns and furnishers of ceramic equipment and supplies. The need for the larger economies obtainable through better controlled materials and processes and the need for greater market strength because of better quality ware makes a Society of this sort not only desirable, but absolutely necessary if the several ceramic industries are to maintain themselves in competition.

The members collaborating through this organized agency of their own, are making every effort and studying every means whereby advances may be made in methods of

production and quality of product, so that the owners of manufacturing plants may better hold their own in competition.

Each member of the SOCIETY will be assisting himself and his fellow ceramist by presenting to corporations the advantage of corporation support so that the personal members may enjoy the rights and benefits of this SOCIETY at a cost within their means.

It should be pointed out with pride that this SOCIETY has kept its personal membership dues to the low figure of $10.00 per year and has never called for an assessment. The SOCIETY operates within its budget and cannot extend its services without a larger personal and corporation support.

We wish to point with a great deal of pride to the fact that the amount of literature published each year and the amount of world's literature abstracted each year has been increasing. This year, measured in number of pages, the SOCIETY has published thirty more pages of original technical papers and sixty-two more pages of abstracts of the world's literature.

A *Bibliography* of the world's literature on refractories, compiled most largely by the instructional force at the University of Illinois, is indexed and in page proof, has been given final editorial reading and is ready for issuance. The compilation of this bibliography required on the part of the instructional force at University of Illinois and other members of the Refractories Division a considerable number of hours of patient, tedious labor, and it has cost the SOCIETY a considerable amount of money to put it in form for printing editorially. The SOCIETY assumes a large obligation in issuing this *Bibliography*, for bibliographies are expensive to compile and to publish. Being a technical organization not engaged in business for financial profit, it must depend upon support of the manufacturers in order to issue this *Bibliography* at a cost within the means of the SOCIETY to issue and persons to purchase.

Personal and corporation application blanks will be sent on request.

NEW MEMBERS RECEIVED FROM OCTOBER 15 TO NOVEMBER 16

PERSONAL

Raymond C. Benner, Director of Research, The Carborundum Co., Niagara Falls, N. Y.
Walter F. Cameron, Student, Delavan, Ill.
Earle M. Champion, Jr., Candler Bldg., Atlanta, Ga.
John B. Christensen, Jr., Student, 603 E. White St., Champaign, Ill.
Clarence Z. Eatherton, Student, 56 W. Woodruff Ave., Columbus, Ohio.
Ernest G. Enck, Salesman-Chemist, Foote Mineral Co., 1421 Arch St., Philadelphia, Pa., Room 534.
H. E. Fear, Salesman, Proctor-Schwartz Inc., Hotel Metzger, Salem, Ohio.
Wilbur F. Fischer, Student, 131 Hyland Ave., Ames, Iowa.
Alex. E. Fitzgerald, Student, 206 E. Green St., Champaign, Ill.
Reginald W. Holmes, Craigower New Road, Llanelly, S. Wales.
Robert F. Kohler, American Encaustic Tiling Co., Zanesville, Ohio.
Hilton L. Longenecker, Superintendent, Carolina Fireproofing Co., Gulf, N. C.
Gustav E. Lundell, Chemist, Bureau of Standards, Washington, D. C.
Elmer A. Meents, Student, 478 S. Wildwood Ave., Kankakee, Ill.
Shuichi Nuriya, Assistant Ceramic Engineer, c/o Iga Yogyo Co., Uenomachi, Micken, Japan.
Wm. A. Ouwenell, Superintendent, Continental Faience and Tile Co., 707 Marshall Ave., So. Milwaukee, Wis.
Giulio Richard, Ceramist, Via Antonio Beretta 8, Milano, Italy.

Herbert J. Shaner, Firebrick Sales, Chicago Dist., c/o The Babcock & Wilcox Co., Marquette Bldg., Chicago, Ill.

Christian W. Svendsen, Superintendent, Pomona Tile Mfg. Co., 672 San Francisco St., Pomona, Calif.

CORPORATIONS

Chattanooga Stamping & Enameling Co., James E. Abshire, Secy.-Treas., Chattanooga, Tenn.

Foote Mineral Co., H. C. Meyer, Vice pres., 1609 Summer St., Philadelphia, Pa.

A. P. Green Fire Brick Co., A. P. Green, Pres., Mexico, Mo.

National Enameling & Stamping Co., John F. Blackie, Gen. Mgr., 425 E. Water St., Milwaukee, Wis.

Pittsburgh White Sand Co., Silica Sand, W. L. Stevenson, Representative, Farmers Bank Bldg., Pittsburgh, Pa.

Membership Workers' Record

	Personal	Corporation		Personal	Corporation
A. I. Andrews	1		M. Ichijo	1	
H. H. Blau		1	T. N. McVay	1	
J. E. Brinckerhoff	2		A. Malinovszky	1	
Paul E. Cox	1		C. W. Parmelee	2	
Harold R. Feichter	1		E. P. Poste		1
M. L. Hartmann	1		A. S. Watts	1	
P. D. Helser	1		W. H. Zimmer	1	
M. E. Holmes		1	Office	5	2
			Total	19	5

MINUTES OF THE MEETING OF THE STANDARDS COMMITTEE OF THE GLASS DIVISION OF THE AMERICAN CERAMIC SOCIETY OCTOBER 28, 1926

The meeting was called to order in the office of the AMERICAN CERAMIC SOCIETY with every member present.

Dr. Lundell reported that he would have a sample of standard glass prepared in a few weeks to be sent out and analyzed preparatory to putting it on the shelves as a standard sample. Dr. Lundell also reported that the dolomite limestone would be ready in two weeks.

The use of tantalum to replace platinum ware in the evaporation of carbonate fusions was again brought up. So far experiments carried on by Mr. Reed seem to indicate that the tantalum is attacked by the silica in the solution, forming a corrosive ring on the dish at the level of the solution. Porcelain and Pyrex act in the same manner. Further experiments are going to be made on this.

Results of routine methods of analysis of glass as handed in by the coöperating analysts, were thoroughly discussed by the Committee. There was considerable variation in detail between most of the methods.

Variations of results from the accepted analysis of the Bureau of Standards indicated in some cases where the methods were wrong.

Dr. Lundell produced some comparisons of some very thorough work on methods of analysis as done at the Bureau in which he had worked on a comparison of the use of sulphuric and perchloric acids as dehydrating agents for silica and in which he had compared various short cuts as habitually taken by routine analysts with the umpire methods used at the Bureau. This work was so thorough and checked so well with

indications of the methods of analysis as sent in, that it was made the basis of decision as to what methods to use in the routine analysis.

The committee wrote out a routine method, based on considerations of the methods as sent in, Dr. Lundell's work, and general references to methods of analysis.

This tentative method of analysis is being written up, will be looked over by each member of the committee and will finally be recommended to the February meeting of the SOCIETY for vote as the standard method.

Dr. Lundell agreed to write up the umpire method so that each analyst of the standard glass could use it as well as the routine method in making his analysis.

Mr. Schurtz and Mr. Reed were to prepare a quick method for emergency analysis, two or three methods being available.

Standards Committee, Glass Division, AMERICAN CERAMIC SOCIETY. Reading from left to right. Standing, F. C. Flint, C. A. Walworth, Carl Reed, R. C. Purdy. Seated: A. A. Payne, G. E. F. Lundell, K. C. Sanders, D. D. Schurtz.

Mr. Schurtz agreed to get a sample of finely ground sand with iron content between .04 and .05% so the Bureau could use it as a standard for iron only.

Those attending the meeting were G. E. F. Lundell, Chemistry Division, Bureau of Standards, Washington, D. C.; A. R. Payne, Hazel-Atlas Glass Company, Clarksburg, W. Va.; C. A. Wallworth, Chief Chemist, Libbey-Owens Sheet Glass Company, Charleston, W. Va.; D. D. Schurtz, Sharp-Schurtz Company, Lancaster, Ohio; F. C. Flint and K. C. Sanders, Hazel-Atlas Glass Company, Washington, Pa.; Carl Reed, Sharp-Schurtz Company.

GLASS DIVISION BY-LAWS CARRY VOTE

The official count of the vote on the proposed by-laws of the Glass Division of the AMERICAN CERAMIC SOCIETY was thirty-two for the by-laws and one against. There

was one reservation in which it was suggested that article 7 was unnecessary and that the Secretary of the SOCIETY should certify that the by-laws do not interfere with the Constitution of the SOCIETY. The provision was put into the original by-laws to take care of any future additional laws as well as the present ones. The by-laws appeared in the September issue of the *Bulletin*, pp. 374–75.

NEWS FROM THE LOCAL SECTIONS

Northern Ohio Local Section Meeting, November 1

Twenty-seven gathered for dinner at Hotel Winton and a few others came in afterwards to attend the meeting. Talks were given by J. E. Hansen of the Ferro Enameling Company, Tom Curtis of Vitrefrax Company, and Ross C. Purdy, General Secretary of this SOCIETY.

There was a very animated recital of experiences and discussion of the possibilities of mullite refractories and of the proposed Ceramic Research Council. Led by Robert D. Landrum there were several who discussed favorably the proposed Council to be organized by ceramic manufacturers. It was the consensus of opinion that the sponsoring and the putting across of this proposal was a task rightfully within the scope of the AMERICAN CERAMIC SOCIETY.

Ceramic education and the curricula of ceramic schools was discussed. Although there were only four present who had attended a ceramic school it seemed to be quite unanimous that specialization in ceramics was excellent, but the substance of the courses would have to be brought up to date in keeping with industrial requirements.

The Baltimore-Washington Section Meeting[1]

The first meeting of the Baltimore-Washington Section of the AMERICAN CERAMIC SOCIETY for 1926–27 was held at the Lee House, Washington, D. C., October 23, 1926. Thirty-one members were present at the dinner. As each member arrived he was "buttonholed" with a card bearing his name, a first step in Chairman A. N. Finn's plan to have everyone acquainted with everyone else, which was followed by having each member introduce another member.

The program was opened by a paper on "The Abrasive Resistance of Ceramic Glazes," by A. C. Harrison of the Bureau of Standards. The paper covered the progress of the work being carried on at the Bureau of Standards by the author. Factors influencing the resistance of glazes to abrasion and the methods for measuring the degree of abrasion were well discussed.

"Enamel Coloring Oxides, Their Composition and Production" by H. G. Wolfram brought out the factors which govern the reproduction in practice, on a commercial basis, of a laboratory development in colored enamels.

The following committees were appointed to serve the Section for the Season: Committee on By-laws and Constitution, R. F. Geller, B. T. Sweely, R. R. Fusselbaugh, D. H. Fuller, H. Insley. Program Committee, B. T. Sweely, Mr. White, D. E. Parsons, A. C. Harrison. Membership Committee, H. G. Wolfram, W. B. Pimm, Jr., Mr. Swicker, W. N. Harrison. Entertainment Committee, R. R. Fusselbaugh, R. Turk, C. B. McComas.

[1] Received November 3, 1926, C. B. McComas, Secy.-Treas.

Curtis Addresses Pittsburgh Section

At the last regular monthly meeting of the Pittsburgh Section, AMERICAN CERAMIC SOCIETY, November 3, 1926, T. F. Curtis gave an informal talk on mullite refractories. The meeting was well attended and proved to be of interest especially to manufacturers and engineers who work with refractories.

Mr. Curtis ably reviewed his original studies of sillimanite as well as the present day super-refractories. He pointed out that traces of certain fluxes such as magnesia and lime were injurious while potash up to a content of 3% was not particularly detrimental. Corrosive effects of fuel oils containing sulphur and sodium chloride, particularly those from the Pacific Coast, were explained.

Mr. Curtis reviewed the requirements of refractory brick and tank blocks. The former is preferably made up of comparatively small particles of vitreous grog which give strength to the brick because of their intimate mixture. The longer and larger particles, combined with a binder which when at operating temperatures is more viscous than the molten metal, are desirable in tank blocks.

Another interesting feature was the recommendation of glycerine for use in determining the effective porosity rather than water. It was pointed out that glycerine penetrates in a similar manner to the molten metal.

The talk was followed by a discussion in which it was brought out that a properly manufactured aluminum silicate would cause a matted structure in saggers producing additional strength.

On October 14, twenty members of this Section visited the plant of the Westinghouse High Voltage Insulator Company at Derry, Pa. E. H. Fritz, H. M. Kraner, and Mr. Ryan showed the members through the plant, which included the slip preparation, casting, molding, turning, and laboratory departments. Each piece of ware is tested for its electrical resistance and although perfect from a ceramic viewpoint it may be scrapped at this point.

Joint Local Section Meeting at Illinois

The Chicago, Northern Ohio, and St. Louis Sections of the AMERICAN CERAMIC SOCIETY held a joint meeting at Urbana, Illinois, on November 19 and 20. Eighty-five members of the three sections were present. In addition there was an excellent attendance of local men interested in furthering ceramic work in Illinois.

The decision was made to organize an Illinois Ceramic Industries Association similar to the Ohio Ceramic Industries Association. Mr. Purdy, as Secretary of the AMERICAN CERAMIC SOCIETY, was asked to assist with the organization of this Association.

A large number of those present at this meeting attended the Ohio State-Illinois football game as a feature of Saturday.

The program presented was as follows:

"The University's Place in Research," by Cullen W. Parmelee, Ceramic Department, University of Illinois.

"Research and Its Advantages," by Ross C. Purdy, General Secretary, AMERICAN CERAMIC SOCIETY.

"Problems in Glass Where Research Can Help," by C. H. Modes, Illinois Glass Co., Alton, Ill.

"Problems in Sanitary Ware Where Research Can Help," by J. W. Wright, Laclede Christy Clay Products Co., St. Louis, Mo.

"Problems in Firing Where Research can Help," by Mr. Weber, Russell Engineering Co., St. Louis, Mo.

"Problems in Electrical Porcelain Where Research Can Help," by P. D. Helser, R. Thomas & Sons Co., Lisbon, Ohio.

"Problems in Heavy Clay Where Research Can Help," by Douglas Stevens, Acme Brick Co., Danville, Ill.

"Problems in Terra Cotta Where Research Can Help," by Barney Radcliffe, Northwestern Terra Cotta Co., Chicago, Ill.

"Problems in Enamels Where Research Can Help," by L. H. Menne, Peoples Gas Light & Coke Co., Chicago, Ill.

"The Type of Research for Government and University Laboratories,"[1] by A. V. Bleininger. An abstract of this paper was read by George Blumenthal.

NOTES AND NEWS

OHIO CERAMIC INDUSTRIES ASSOCIATION

This Association met in Lord Hall on Ohio State University Campus, November 12–13. Addresses were made by J. L. Murphy, General Edward Orton, Frank P. Judge, and Thomas B. Anderson. The burden of the addresses and of the consideration by the attending delegates was how the ceramic industries of the State and the University could collaborate in advancing the economic and technical welfare of the ceramic industries of the State.

With the high school course established at East Liverpool, a ceramic art department adopted by the College of Arts and approved by the President of the University, establishment of a ceramic division in the Engineering Experiment Station with a full time research professor in charge, a working agreement with the Welfare Board for the establishment of a plant size experimental plant in conjunction with one of the prison brick yards with adequate state appropriation support; with these as accomplished achievements the Association considered ways and means of extending and making permanent these research and educational facilities within the State.

A considerable attention was paid to the clay mining survey which is now being made throughout the State for purpose of making critical recommendations to the different clay miners. This project is sponsored jointly by the University and the Ohio Ceramic Industries Association.

The following officers and members of the Board of Trustees were elected: J. L. Murphy, chairman, W. K. McAfee, vice-chairman, C. B. Harrop, treasurer, G. A. Bole, secretary. E. O. Biglow, drain tile, W. C. Senn, electric porcelain, T. B. Anderson, general ware, S. J. Scholes, glass, C. F. Tefft, common brick, C. H. Taylor, refractories, John Martin, face brick, T. J. Evans, sewer pipe, J. D. Whitmer, wall and floor tile, J. B. Whitaker, building tile. Enamels, not elected. Stoneware, not elected.

N.B.M.A. TO MEET IN COLUMBUS

The forty-first annual convention of the National Brick Manufacturers' Association will be held January 11–13, 1927, at Columbus, Ohio. The Neil House will be headquarters for this meeting. The Wednesday morning session (Jan. 12) will be given over largely to a memorial session in honor of Theodore A. Randall. The other sessions will consist of symposiums and papers dealing with subjects of special interest to plant operators. Friday will be devoted to a trip through the plant of Dr. De Muth at New Philadelphia, Ohio.

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[1] Published in *Bull. Amer. Ceram. Soc.*, 9 (10), 386–90 (1926).

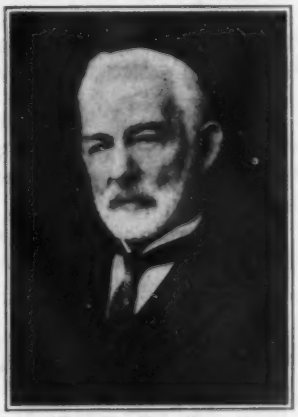
Douglas F. Stevens, the new Secretary of the Association, will be in charge of the program. Mr. Stevens was appointed Secretary at a conference of the Executive Committee of the N.B.M.A. held at Columbus, Ohio, Oct. 8, 1926. James E. Randall had been previously appointed secretary pro tem to succeed his father, the late T. A. Randall, but at this meeting urged the election of a manufacturer of clay products as the best means of promoting the interests of the work of the N.B.M.A. at this time. Mr. Randall stated that while he personally would take great pride in carrying on the work so unselfishly done by his father throughout the past forty years, still the Association was an organization for the brick manufacturer. In Mr. Randall's opinion, if the manufacturers are to appreciate the many benefits carried on, they should exert every effort to maintain the interest and further every movement undertaken for the well-being of the Association.

The Executive Committee accepted Mr. Randall's resignation and voiced its appreciation of the high and unselfish motives which actuated Mr. Randall's action.

Mr. Stevens, of the Acme Brick Company, Danville, Illinois, served as president of the N.B.M.A. in 1925 and has taken an active interest in Association affairs for many years. He is ably suited to the work of Secretary of this organization.

GEORGE IRA ALDEN[1]

George Ira Alden, chairman of the board of directors of the Norton Co., Worcester, Mass., died recently at his home in Princeton, a suburb of Worcester. While a notable inventor and organizer, Professor Alden's chief work in life, and probably his chief joy, came in the rôle of educator. He was born in April, 1843. In 1868 he was graduated from the Lawrence Scientific School of Harvard University, and since that time had received many honors. Cornell University awarded him the degree of master mechanical engineer in 1890. The Worcester Polytechnic Institute and the Washburn College, Topeka, Kans., both conferred honorary degrees on him during the past year. For many years he was instructor and later professor of the Worcester Polytechnic Institute, and for 28 years he was head of the mechanical engineering department of this school. During this time he twice served as temporary president, and it was while he was devoting much of his time and enthusiasm to the collegiate work that he carried on his commercial enterprises. Associated with Milton P. Higgins, he organized the Plunger Elevator Co. in Worcester, which Company was later taken over by the Otis Elevator Co. Shortly after this time he and Mr. Higgins organized the Norton Co. in a small building on Water Street, in Worcester. He served as treasurer of the Company from its organization until the death of Mr. Higgins in 1912, when he became president. In addition to this he was treasurer and general manager of the Norton Grinding Co. from 1900 until 1919 when the Norton Co. and the Norton Grinding Co. merged, at which time he became chairman of the board of directors of the new Norton Co.



GEORGE IRA ALDEN

The death of Professor Alden marks the passing of one of the few remaining characters associated with the earliest days of the grinding industry. It was in 1885 that the possibili-

[1] *Abrasive Industry*, November, 1926.

ties of a vitrified wheel were foreseen by John Jeppson, Milton P. Higgins, and George I. Alden with the result that the Norton Emery Wheel Co. came into a humble existence. Mr. Alden saw the first vitrified grinding wheel made by Mr. Jeppson in the pottery shop of F. B. Norton, Worcester, Mass., in 1873. The abrasive used was emery. This was mixed with the clay and bonded into wheel shape with crude modeling instruments similar to those used in production of pottery. The wheels were fairly successful, but there seemed to be little market and nothing was done for about six years. In 1879 Mr. Jeppson again started making wheels in his pottery shop, and this time a salesman was employed. It was, however, another six years before Mr. Higgins and Professor Alden gave the industry its real start through the formation of the Norton Emery Wheel Co. He saw the abrasive industry develop from meager beginnings to its present day place.

NOTES FROM THE BUREAU OF STANDARDS[1]

Thermal Expansion of Graphite

An investigation on the thermal expansion of longitudinal and transverse samples of artificial graphite (containing 99.2 to 99.7 % carbon) over various temperature ranges between room temperature and 600°C has been completed. The coefficients of expansion of graphite are low. For example, the coefficient of expansion of ordinary steel is about six times the coefficient of longitudinal graphite and about four times the value for transverse graphite between 20 and 100°C. The transverse samples expand considerably more than the longitudinal samples (approximately 45 %). For the longitudinal or transverse samples the coefficients of expansion decrease slightly as the purity increases.

The small expansion of graphite is an important factor in the resistance of graphite to sudden temperature changes. Plunging samples at 600°C into cold water did not cause breakage or cracking.

Artificial graphite finds wide applications in the industries. It is used very largely for electrodes of electric furnaces, for anodes of electrolytic cells, for the making of molds for casting metals and glass, for electrical heating elements of various sorts, for electrical contacts and arcing tips, etc. In granular or powdered form, artificial graphite is used in large quantities in the manufacture of dry cells, radio batteries, and also for paint pigment, mold wash, lubricants, resistors, powder glazing, and electro-typing.

Specifications for Vitrified Chinaware Revised

The United States Government Master Specification for Vitrified Chinaware No. 121, adopted November 5, 1924, has been revised and issued as No. 121a, dated September 25, 1926.

The revision of the specification was necessitated chiefly by the fact that some of the tests prescribed were apparently too rigid, and also by the requirements of the various branches of the Federal Government for shapes of ware not included in the original specification.

The revision was thoroughly discussed and approved at a conference between the American Vitrified China Manufacturers' Association and the Federal Specifications Board's technical committee on chinaware which was held at the Bureau on May 11, 1926. The most significant changes were: (1) the elimination of all minimum (or maximum) values on any single piece, the evaluation being based on averages alone; (2) the elimination of the quenching test; and (3) a reduction in certain impact and

[1] *Tech. News Bull.*, No. 114, October, 1926.

chipping values and an increase in others. Some changes in wording were also made to clarify certain statements of questionable meaning, and four new shapes were added.

The revised specification covers 71 different items in three weights: viz., thick china, hotel (rolled edge) china, and medium-weight china. It contains an itemized list giving the name, trade size, actual size, tolerances in size, maximum weight, and sectional drawings of each piece. It also specifies the maximum absorption allowed and the minimum resistance to impact, chipping, and quenching. The apparatus and the methods of making the physical tests are described in detail.

Effects of Composition on the Properties of Ground Coat Enamels for Sheet Steel

The present commercial vitreous enamels for sheet iron and steel, used in the production of enameled kitchen ware and similar articles, are very limited in types of composition. Fundamental researches conducted at the Bureau and elsewhere have developed valuable information for the industry, but the application of the findings has been hindered by the limitations of present compositions. In an effort to relieve this situation the Bureau has studied new fields of ground coats and cover coats, and a report on the cover coats was published in *Technical News Bulletin* No. 104, December, 1925.

In the work on ground coats a series of compositions was planned about each of three refractory bases, one was flint and feldspar, another consisting of feldspar only, and the third of flint only. A fixed minimum of metallic oxides, boric oxide, and sodium oxide was used throughout. The variable portion in each series was made up of equal parts of three constituents, chosen from a total of six in such a way that every possible combination was employed. These six constituents were boric oxide, sodium oxide, cryolite, fluorspar, lead oxide, and zinc oxide. The ground coats were applied to 8-inch dinner plates, covered with two coats of a standard white enamel, and tested for resistance to mechanical and thermal shock.

Analysis of the data indicated the existence of several rather clear-cut general relationships, as follows:

1. A high feldspar content in ground coats, produced by replacing the customary flint content with feldspar, greatly decreased resistance to mechanical and thermal shock.
2. A high flint content in ground coats, produced by replacing the usual feldspar content with flint, improved the resistance to mechanical shock.
3. Of the six variable constituents studied, a high sodium oxide content in ground coats was outstandingly conducive to a high resistance to both mechanical and thermal shock.
4. A high boric oxide content increased resistance to mechanical shock.
5. Expansivity of the ground coats did not appear to be as powerful a factor in its effect upon resistance to mechanical and thermal shock as it has been proven to be in its effect upon fishscaling.

RICH DEPOSIT OF CYANITE ORE IN YANCEY COUNTY[1]

Discovery of rare mineral deposits at Burnsville, in Yancey County, focusing the attention of the entire ceramic industry upon western North Carolina, is officially announced by J. A. Pollard, president of the Yancey County Chamber of Commerce and head of the Pollard Clay Company.

Valued at millions of dollars there has been located upon the Appalachian Scenic Highway route two miles from Burnsville, and in plain view of that heavily travelled artery, three mountains bearing deposits estimated to run unto the millions of tons of

[1] *Asheville Citizen*, Oct. 28, 1926.

cyanite, heretofore regarded commercially as one of the rarest of non-metallic minerals. It is employed as a so-called "super-refractory" in the ceramic industry in the making of electrical porcelains, and is just now coming to the forefront as a product of importance for the manufacturing of crucibles, glass pots, and similar containers able to withstand repeatedly extremely high temperatures.

The quality and quantity of these deposits has been demonstrated by repeated offers already received from representatives in this field, including internationally known German syndicates.

Appraisal made by J. L. Stuckey, state geologist, after personal inspection of the deposit gives these deposits a reputation for potentialties of immense wealth. In the opinion of the other experts who have examined the deposit, the richness of the mineral, its ease of access to the state highway and railway facilities within one mile of the property, with the composition of the major materials indicating little expense in separating from the pure cyanite by concentration, it is believed that Yancey County deposits will prove one of the greatest "finds" ever made of ceramic raw materials. Ample low-cost hydroelectric power and gravity water supply available at the deposits are factors of prime importance.

While cyanite has been found in "museum specimens" the world over, with plentiful out-croppings scattered throughout western North Carolina and other southern states, the search for commercial deposits of real value has carried experts into far corners of the globe. The Yancey County deposits are reported to be contained in a friable schist, and run from 10 to 40% cyanite, even to as high as 90% of the containing ore bodies.

Not until the meeting of the AMERICAN CERAMIC SOCIETY in Atlanta, Ga., last February did Mr. Pollard finally realize the real possibilities lying upon the 5,000-foot mountain peak in the Land of the Sky. G. A. Bole, then of the Bureau of Mines, Columbus, Ohio, informed the Yancey County mine operator that the ceramic industry was seeking a cyanite deposit held in soft schist, milling out at least 10 to 12% pure cyanite. Likelihood of such a discovery was considered almost a dream.

Just a few days ago Mr. Pollard says he placed in safety deposit the final papers covering a unified boundary of 450 acres upon which lie the rich mineral deposits.

Miss Mary Smith, 189 Chestnut St., Asheville, N. C., also reports 600 acres of excellent cyanite.

SOCIETY OF GLASS TECHNOLOGY

The first meeting of the Society of Glass Technology for 1926–27 was held in Leeds, England, October 20, 1926. The following papers were presented:

1. "Glass Annealing," by J. W. French. In any discussion of annealing the first question is the rate at which heat is dissipated by glass at the various temperatures of the annealing process. The second is the thermal expansion or contraction of the material. An average value of the thermal linear expansion coefficient for glass was 0.000,008,5. Thermal conductivity is the third question: an average value of the conductivity is about 0.002. Copper has a conductivity 500 times as great. Glass is more liable to crack when heated rapidly than when cooled at the same rate. The other conditions determining the magnitude of the stresses that might be established in glass during the cooling process are: (4) cohesion of the material, (5) the viscosity of the glass, (6) the existence of a surface layer having properties different from those of the underlying material, (7) homogeneity of the glass, and (8) the form and dimensions of the glass.

The results of defective annealing in glassware and optical glass were noted; the means of detecting stresses was indicated with special reference to the use of the polariscope, and the methods of annealing were explained. From the optical glass point of view,

annealing means: (1) the raising of the temperature to a point just above that of the hardest glass in the charge, and (2) the cooling of the plant at a rate which would not at any one point be sufficient to re-introduce stresses in any of the glasses. If cooling curves were plotted for all the varieties of glass, the charge should then be cooled in accordance with a curve which was the envelop of all the others. According to a method based on that of Guinand, a pot of glass was allowed to cool down comparatively quickly, the rate of cooling being such that the mass would break down into pieces of a workable size. These pieces were chipped to the weight of the required rough blocks, then placed in fireclay molds stacked in ovens. These ovens were heated until the pieces melted down and filled the molds. They were then allowed to cool at a prescribed rate, from three to four, and in some cases five weeks being allowed for the cooling operation.

2. "The Economics of the Annealing Process," by E. A. Coad-Pryor. An account was given of the experiments on which the Engineering Department and the Research Laboratories of the United Glass Bottle Mfgrs. Ltd. has been recently engaged at Charlton. Ideal cooling curves for glass during the annealing process were most difficult to interpret into works practice, because they represented the temperature of the glass and not the temperature of the leer. It was found that, by suitably grading the insulation of the entire leer, it was possible to carry out rapid cooling without the aid of any induced draft; and further, that a leer could be built which would anneal any size of bottle without any adjustment or damper regulation.

In order to get the information on which to design a leer, on a sound theoretical basis, it was necessary to know the amount of heat taken into the leer by the bottles and the heat lost through the leer walls. Experiments to determine these factors were described. It was interesting to find that an alteration in the weight of the bottle being annealed did not greatly affect the heat balance, because, although the bottles took less heat into the leer, the annealing time was very much less, and, therefore, they had only to balance the heat in the bottle with that lost from a smaller portion of the leer. Although it was quite easy to raise a body temperature of 60°C with a fair degree of efficiency, it was not at all easy to add 10° to a body already at, say, 550°C. Eventually they decided to supply heat to the leer by means of the slats of the conveyer, and an experimental leer, embodying the principles outlined was built and proved very interesting and successful. The fuel consumption was about 18,000,000 B.t.u.'s per day, that is, just over 100 gallons of oil or 1500 pounds of coal of calorific value, 12,000. During most of the period of testing the leer was running at about one-third of its maximum speed. The annealing was good throughout. They speeded it up to its maximum rate, about 10 inches a minute, and the annealing remained excellent, even on the quart bottles. This speed represented an output of 450 gross of quarts per day, or about 40 tons of glass.

The leer was fitted with a number of curtains to restrict draft up the tunnel. They found that once the curtains were adjusted to the correct setting no further adjustments were required. A thermocouple was placed in the slat-heating chamber, close to the slats, and the only work the operator had to do was to see that the couple registered the required temperature. They found that the leers well retained their heat for many hours, and consequently, if the machines were shut down (for a change of job) and the leer was run idle for a few hours, the first bottles through after starting up again were well annealed.

3. F. A. Hurlbut described a suggested improvement in the design of the leer conveyers.

4. A new type of fireless leer was exhibited by slides. The leer was designed by the Hartford-Empire Company, of the United States and the paper was presented by E. Meigh.

5. "The Relationship between Chemical Composition and the Upper Annealing Temperature of Glasses," by S. English and W. E. S. Turner was listed but not read.

CALENDAR OF CONVENTIONS

Amer. Assn. Advancement of Sci.	Dec. 27, 1926–Jan. 1, 1927	Philadelphia, Pa.
AMERICAN CERAMIC SOCIETY		
Annual Meeting	Feb. 14–19, 1927	Detroit, Mich.
Amer. Chemical Society	April 11–16, 1927	Richmond, Va.
Amer. Electrotechnical Society	April 28–30, 1927	Philadelphia, Pa.
Amer. Engineering Council	Jan. 13–15, 1927	Washington, D. C.
Amer. Face Brick Assn.	Nov. 30–Dec. 2, 1926	French Lick Springs, Ind.
Amer. Gas Assn.	Oct. 10, 1927	Chicago, Ill.
Amer. Inst. Min. and Met. Engrs.	Feb. 14–17, 1927	New York City
Amer. Mining Congress	Dec., 7–10, 1926	Washington, D. C.
Amer. Soc. Mech. Engrs.	May 23–26, 1927	White Sulphur Springs, W. Va.
Amer. Sci. App. Makers	April, 1927	?
Can. Natl. Clay Prod. Assn.	Feb. 8–12, 1927	Toronto, Canada
Common Brick Mfrs. Assn.	Feb. 21–26, 1927	Chicago, Ill.
Glass Container Assn.	April or May, 1927	?
The Gypsum Industries	Dec. 7–8, 1926	Chicago, Ill.
Hollow Bldg. Tile Assn.	Feb. 9–11, 1927	Chicago, Ill.
Mining and Metallurgical Soc. of Amer.	Jan. 11, 1927	New York City
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March 8, 1927	Pittsburgh, Pa.
Natl. Brick Mfrs. Assn.	Jan. 11–13, 1927	Columbus, Ohio
Natl. Exposition of Power and Mech. Eng.	Dec. 6–11, 1926	New York City
Natl. Paving Brick Mfrs. Assn.	Dec. 15–16, 1296	Washington, D. C.
Natural Gas Assn. of Amer.	May 17–19, 1927	Cincinnati, Ohio
New Jersey Clay Workers Assn.	Dec. 17, 1926	New Brunswick, N. J.
Society of Glass Technology	Dec. 15, 1926	London, England
(Eng.)	Jan. 19, 1927	Manchester, England
	Feb. 16, 1927	Sheffield, England
Stained Glass Assn. of Amer.	June 27, 1927	St. Louis, Mo.
Taylor Society	Dec. 8–11, 1926	New York City
U. S. Potters Assn.	Dec. 7–8, 1926	New York City

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A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical and Scientific Questions and Promotion of Coöperative Research.

VOLUME 5, 1926

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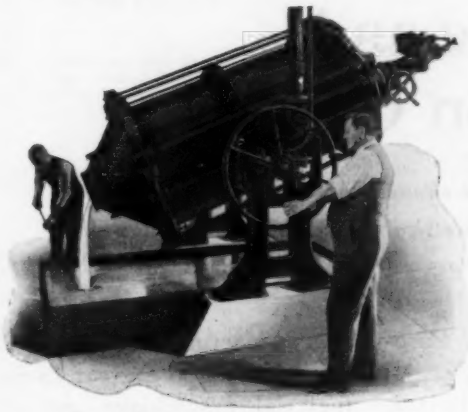

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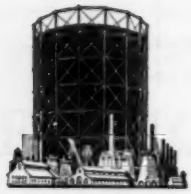

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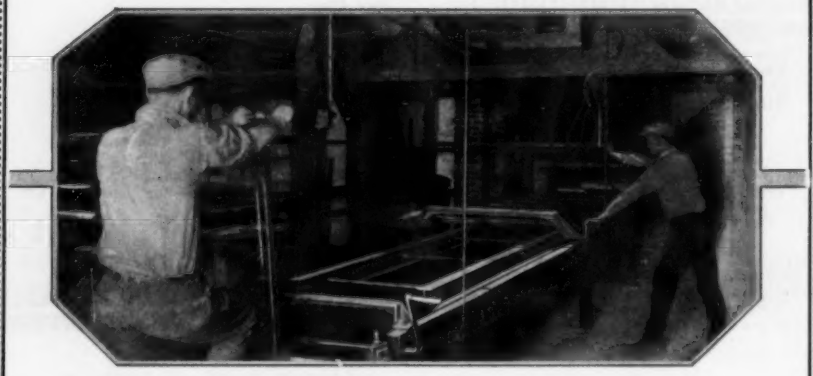

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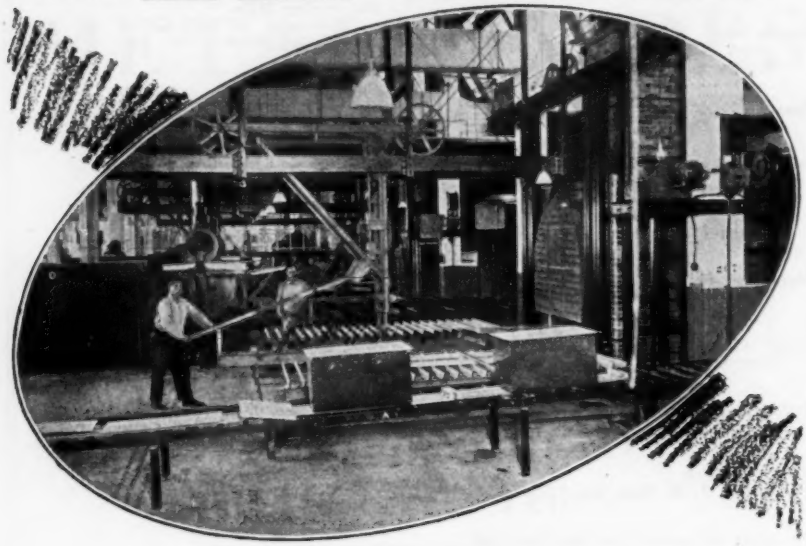

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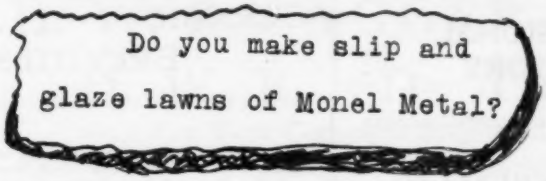

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Robert Long, formerly employed by the Cribben & Sexton Company of Chicago, Ill., has recently been appointed assistant superintendent of the Wolverine Porcelain Enameling Company of Detroit, Michigan, a subsidiary of the Porcelain Enamel & Mfg. Company of Baltimore.

Mr. Long succeeds Oscar W. Kraft, who has left the subsidiary company to join the Service Department of the parent company at Baltimore.

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CERAMIC BREVITIES

Albert W. Thime, formerly of the Stowe-Fuller Refractory Company and the Carborundum Company, has joined the sales organization of The Porcelain Enamel & Mfg. Co. of Baltimore, Md.

Mr. Thime is an experienced furnace man and will make a valuable addition to the sales force of the enamel company.

It is expected that he will be assigned to one of the western territories in the near future.

It is announced by the Regent Stove Company of Detroit, Mich., that they have let a contract for the installation of complete enameling equipment for applying enamels to cast iron and sheet steel, with the Porcelain Enamel & Mfg. Company of Baltimore.

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Information reaching this country indicates that Shu-Yung Lui, Boxer Scholarship student at Ohio State University and the Pemco School of Practical Enameling, 1922, has returned to China and made an astonishing financial success by introducing American methods and ideas to the Chinese enameling industry.

Finding the Chinese market overrun with inferior enameled products from Europe, which commanded exorbitant prices, Mr. Shu-Yung organized the Southwestern Ceramics Company, a million dollar organization which he now heads as chief engineer.

Activities of the American press in running down details of his career indicate that his success has been exceptional.

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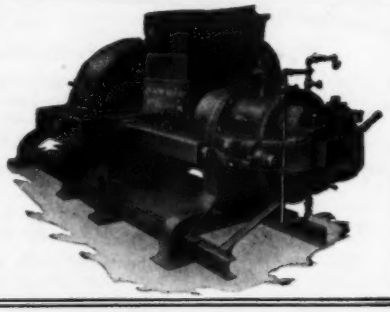

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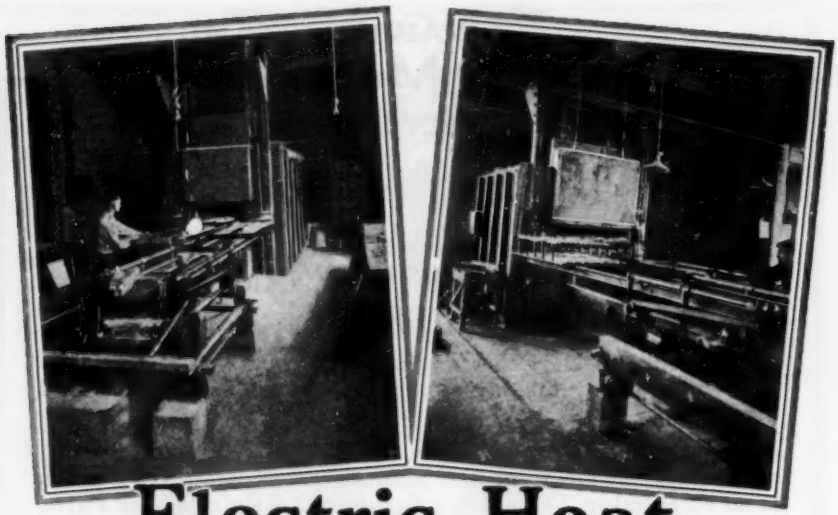

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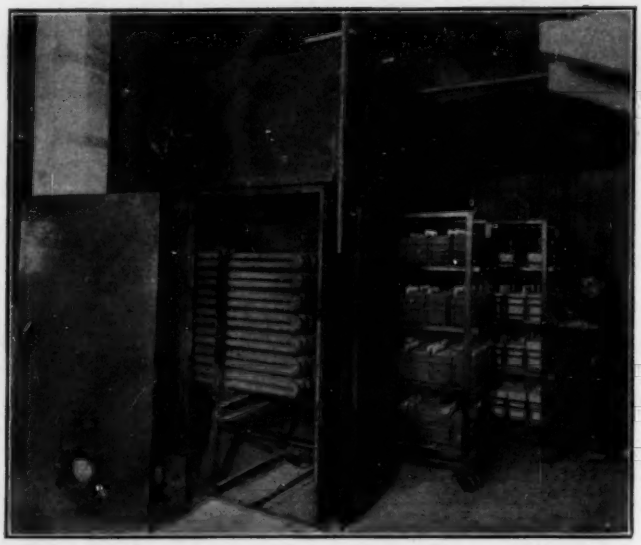

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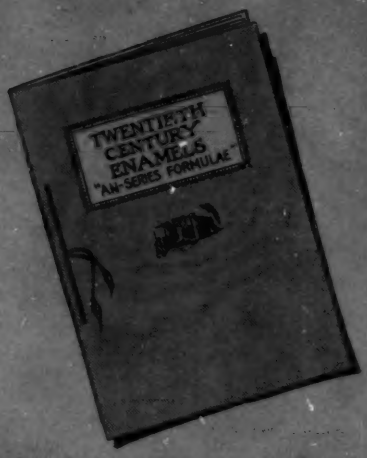

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